



**Learning to Become a Physics Inquirer:
Environment, Process, and Challenges**

Doctoral Dissertation

Submitted by Michal Sigron

Supervisor: Prof. dr hab. Stanisław Dylak

Faculty of Educational Studies

Adam Mickiewicz University of Poznań, Poland

January 2021

This study took place in the context of a pedagogical lab - the 'Research Physics' program - headed by Prof. Edit Yerushalmi from the Department of Science Teaching, Weizmann Institute of Science, and carried out within the Institutional framework of the Davidson Institute of Science Education, Weizmann Institute of Science, Israel.

The study is a research collaboration between Prof. Edit Yerushalmi from the Weizmann Institute of Science and Prof. Stanisław Dylak from AMU University in Poznan, Poland.

The institute allowed the researcher, Michal Sigron, to use the pedagogical lab - the 'Research Physics' program – throughout the program period (2016-2019), under the academic supervision of Prof. Edit Yerushalmi.

Any publication of results of the research carried out in the 'Research Physics' Program at the Weizmann institute would be approved by Prop. Yerushalmi and include the relevant lab members' names as authors. The Weizmann Institute retains all copyrights and commercial rights to the research instruments carried out within the 'Research Physics' program.

Acknowledgments

*A wise man said to me: "I have a simple solution when it's hard for you, just put in more effort."
(My father, of blessed memory, Avraham Sigron)*

In slang, when great effort is required, the question is asked: "What is this, a doctorate?" Until you do this, it is impossible truly to understand this question. It was not easy for me to undergo the "journey of the doctorate", which required great investment, prioritization in a changing everyday life, and postponement of other important goals in life. Many people helped me succeed in this journey, and therefore I would like to thank them.

I especially thank my academic adviser from the Department of Science Teaching of Weizmann Institute of Science in Israel, **Professor Edit Yerushalmi**. It was a privilege to work with her and to learn from her wisdom and experience. I thank you for the countless hours of conversation and joint thinking, help and practical and mental support, for the push to do the doctorate in the best possible way. For all this, and for much more, I am grateful.

I thank the staff of the Department of Science Teaching of Weizmann Institute of Science and the staff Davidson Institute, in particular **Professor Bat Sheva Ayalon, Professor Dorothy Langley, Dr. Rami Arieli, Dr. Yarden Ben Horin** for opening to me the door and offering to me the research field, for believing in me especially at the start of my path. I thank **Yetty Varon** for helping me in data processing.

I also would like to thank the development team of the "Research Physics" program, in which this research was conducted, who prepared the course and gave me the opportunity to research this program (to observe the events over three years), in particular **Mr. Zeev Krakover, Dr. Zehorit Kapach, Mr. David Perl, Dr. Zvika Arica, Mrs. Nancy Shalev, Dr. Haim Edri and Alex Rubshtein**, and again **Professor Edit Yerushalmi**.

I thank **Professor Avi Levy**, recommended this research to the Chief Scientist of Israel, so that I could receive the approval to carry out a research on students in Israel.

I also thank the **students** who responded to all my questions (In questionnaires and interviews), with great patience and cooperation in our conversations.

Last but not least, I would like to thank my supervisor from AMU university, **Professor Stanislaw Dylak**, for agreeing to take me under his wing and brought me into the world of research gently, for his good and sharp advices throughout the study period, for collaborative thinking in the planning of the research work, and for his concern about all my needs so that I could succeed in this work.

I thank the **members of my family**. In particular, from the bottom of my heart, I thank **my husband Asaf and my children Abir, Toren, Arad, and Keshet**, who took deep breaths along with me on this journey, for their support and patience throughout all the years of the studies. You are partners in this achievement. I thank **my mother Mazal and my mother-in-law Miriam**, who helped me and tried to make things easier for me throughout the journey of the doctorate.

May everyone be blessed, thank you.

Abstract

This research examines students' learning in the 'Research Physics' program. The 'Research Physics' is a new program in the education system in Israel, in which high school students experience a 3-year learning progression of inquiry activities steadily increasing in their scope. It involves a preparation stage, launched with short, structured activities and ending with mini projects; an intermediate stage, in which students prepare a proposal for a long term open ended research project and summarize their initial explorations in a midterm report; and in the final stage the students make a wide and deep inquiry project that ends with a summative report and external evaluation. All activities are carried out in pairs, each pair inquire a different topic. This educational environment differs from the more common framework for research projects – research apprenticeships programs in scientists' laboratories. The program is performed in well-equipped instructional labs in regional centers. The students' mentors are high school physics teachers, concurrently participating in a professional development workshop for teacher-mentors. The instructional design follows cognitive apprenticeship –teamwork of students and teacher-mentors performing authentic tasks, while the teacher mentor scaffolds students' work.

This research examines students' learning as they perceive it from: 1) the detailed perspective of different inquiry components; 2) the holistic perspective, characterizing the inquiry process promoted by the learning environment. In particular, the research questions:

1) How did students' perception of their development relate to their perception of the experience and challenge in performing various inquiry components along the stages of the 'Research Physics' Program?

2) How did student perceive the learning environment in the 'Research Physics' program along their engagement in the various stages of the inquiry work? In particular: the roles of students and teachers and the learning resources

The research population consists of high school physics students who participated in parallel on the Research Physics Program at the Davidson Institute for Science Education in the Weizmann Institute of Science, Israel (N=34). Research tools consisted of Likert type questionnaires, semi structured questionnaires and interviews and the researcher observations of the program sessions. The analysis combined qualitative and quantitative research approaches, where the qualitative research method helped to characterize the experiences and enrich the evidence and the interpretation of the quantitative research.

With regards to research question 1 - Students' perception of their development as related to their perception of the experience and challenge in performing various inquiry components along the program stages - The analysis revealed four groups of inquiry components differing in the alignment between the extent of development, experience and challenge. In both group 1 (phrasing questions/goals, drawing conclusions, and building content knowledge) and group 2 (choosing a topic, performing an experiment, self-regulation, teamwork with the partner, and written reporting on the inquiry) students report meaningful development in the inquiry components that is commensurate with their report on considerable experience. They differ in that the inquiry practices in group 1 were perceived as more challenging and in group 2 as less challenging. In group 3 (identifying sources of information, using technological aids and a computerized laboratory, building a theoretical model, and teamwork with the rest of the peers) and group 4 (planning an experiment, processing data, and oral reporting on the inquiry) fewer students reported on significant development. They differ in that in group 3 the limited development is aligned with the low degree of experience and challenge that students report in these components. However, the findings regarding group 4 are contrary to our expectation that the degree of development will align with the experience and challenge that the students experience. In this group there are inquiry components in which the students' development was low, although the students experienced these components considerably during the program.

The observations, triangulated with students' reports, suggests that these findings can be explained in that the scaffolding provided for group 4 components did not explicate systematically the difference in the nature of the expert versus the novice knowledge. In contrast, in the inquiry components in the first two groups, where development is commensurate with experience, scaffolding was comprehensive, according to the principles of cognitive apprenticeship (modeling, coaching, fading). Indeed, the students highlighted the important role of the mentors' support in meeting the challenges and enabling their growth in these inquiry components. These findings stress that inquiry practices do not develop spontaneously with the experience, and raise the importance of the continuous modeling and coaching scaffolds to ensure the relationship between the development and experience and challenge in the performance of the inquiry components.

For the purpose of question 2 - Students' perception of the inquiry process in the 'Research Physics' learning environment - three point of view were taken: a) the differences students acknowledge between activities in the laboratory in the school framework and in the 'Research Physics' framework; b) students' attitudes towards the inquiry process, their ability to perform inquiry work,

and the contribution of the Research Physics learning environment to their performances; c) students' satisfaction with the guidance that teachers provided in the Research Physics program.

The analysis reveals many aspects that the students acknowledge as unique to the "Research Physics" program, particularly the mentoring that the teachers provided as well as the autonomy granted to the students, and in addition the learning resources (e.g. equipment, technical assistance) that were realized in this environment. Most students expressed satisfaction with the mentoring and the resources, expertise of the teacher-mentors in the content of the researched topic, providing support and direction with regard to theory and responsiveness to questions (when the students cannot answer by themselves), and in planning the inquiry process as necessary without harm to the students' independence in the inquiry work. The students perceive the "Research Physics" culture as an authentic scientific environment, significantly different from that of the school laboratory. Their active engagement in inquiry activities addressing authentic problems (that are chosen by the students) helps cultivate positive attitudes that reflect interest and appreciation for scientific research methods and to the principles of learning through inquiry, promoting their natural curiosity. They also express positive attitudes regarding their ability to perform the inquiry work and the contribution of the program to their personal growth, first in the aspect of management of the inquiry work: self-regulation of the inquiry work, determination in continuous search for an answer while using critical thinking, resilience and flexibility in coping with the dynamics of the inquiry process while adjusting to changes that occur in the process, in particular with the accompanying frustrations and ability to act under conditions of uncertainty, providing an outlet for creativity in order to find solutions for different problems that arose during the investigation. Other aspects they realize as part of their personal growth are building content knowledge independently and teamwork skills in the inquiry work (between the student partners and between them and the teacher-mentors). Students report that they identify with the scientist's world, understand better the nature of scientific research, have more self-efficacy in engaging in scientific inquiry in the future.

The findings portray the value of comprehensive inquiry activity in the context of long term research projects, that the design of the program was overall productive. Hence, appropriate place should be given in the education to learning environments that offer the students an opportunity to experience authentic inquiry in science. However, the findings point also to pitfalls in the design. For this field, the research provides future improvements for the design of this program and similar ones. The results of the research can be useful in the search for effective teaching methods to advance the subject of inquiry in teaching science in general and in teaching physics in the high school in particular.

Table of Contents

LIST OF FIGURES	V
LIST OF TABLES	XII
INTRODUCTION	1
1. Project Field	1
2. Subject Importance	1
4. Project Importance	5
1. KNOWLEDGE IN THE RESEARCH FIELD – REVIEW OF THE LITERATURE.....	8
1.1 What Is the Inquiry Process? Inquiry in general and in the Teaching of the Sciences in particular	8
1.1.1 The Historical Look at the Development of the Idea of ‘Inquiry’	8
1.1.2 Components of Scientific Inquiry	13
1.1.3 Change of the Perception of the Role of the Student and the Role of the Teacher in the Performance of the Inquiry Process	31
1.1.4 Levels of Inquiry in the Inquiry Process	35
1.2 The Laboratory in the Teaching of Physics and the Integration of Inquiry Activities	48
1.2.1 The Role of the Laboratory in the Teaching of the Sciences	48
1.2.2 The Role of the Physics Laboratory in the Upper (High) School in Israel	50
1.2.3 Number of Tracks that Integrate Inquiry in the Teaching of Physics in the High School in Israel ..	53
1.3 The ‘Research Physics’ Program for Students	61
1.3.1 The Rationale of the ‘Research Physics’ Program and Its Goals	61
1.3.2 The Target Audience of the Program	63
1.3.3 ‘Research Physics’ Program for Students in the Davidson Institute of Science Education in the Weizmann Institute for Science (Research Field)	64
2. RESEARCH METHODOLOGY	74
2.1 Research Design	74

2.2 Project Aims	75
2.3 Research Approach	75
2.4 Research Problem	78
2.5 Research Methods	81
2.6 Research Population	87
2.7 Research Instruments.....	88
2.8 Description of the Data Analysis.....	96
3. FINDINGS AND CONCLUSIONS FOR THE FIRST RESEARCH QUESTION	102
3.1 Findings for Part A of the First Research Question: The Students’ Perception of the Experience and Challenge in the Performance of the Different Inquiry Components	105
3.1.1 Stage 1: Preparation Stage of the Inquiry Project – Experience and Challenge in the Performance of the Inquiry Components (Self-Reporting Questionnaire before the Submission of the “Mini-Project” Report, 10 th Grade)	106
3.1.2 Stage 2: Intermediate Stage of the Inquiry Project – Experience and Challenge in the Performance of the Inquiry Components (Self-Reporting Questionnaire before the Submission of the Intermediate Report, 11 th Grade)	111
3.1.3 Stage 3: Final Stage of the Inquiry Project – Experience and Challenge in the Performance of the Inquiry Components (Self-Reporting Questionnaire before the Submission of the Summative Report, 12 th Grade)	123
3.1.4 Comparison between the Stages (Preparation, Intermediate, and Final) of the Inquiry Project – Experience and Challenge in the Performance of the Inquiry Components.....	136
3.1.5 Main Findings – Students’ Perception of Their Experience and Challenge in the Performance of the Inquiry Components in the Different Stages in the Program	146
3.2 Findings for Part B of the First Research Question: The Students’ Perception of Their Development in the Different Inquiry Components	165
3.2.1 Stage 1: Preparation Stage of the Inquiry Project – Development in the Inquiry Components (Self-Reporting Questionnaire before the Submission of the “Mini-Project” Report, 10 th Grade).....	166
3.2.2 Stage 2: Intermediate Stage of the Inquiry Project – Development in the Inquiry Components (Self-Reporting Questionnaire before the Submission of the Intermediate Report, 11 th Grade)	170

3.2.3 Stage 3: Final Stage of the Inquiry Project – Development in the Inquiry Components (Self-Reporting Questionnaire before the Submission of the Summative Report, 12 th Grade).....	181
3.2.4 Comparison between the Stages (Preparation, Intermediate, and Final) of the Inquiry Project – Development in the Inquiry Components	192
3.2.5 Main Findings – Students’ Perception of Their Development in the Performance of the Inquiry Components in the Different Stages in the Program.....	199
3.3 Findings for Part C of the First Research Question: The Relationship between Development, Experience, and Challenges Experienced by the Students in the Performance of the Different Inquiry Components	214
3.3.1 Stage 1: Preparation Stage of the Inquiry Project (10 th Grade) – Relationship between Development, Experience, and Challenge in the Performance of the Different Inquiry Components (in light of the Observation).....	214
3.3.2 Stage 2: Intermediate Stage of the Inquiry Project (11 th Grade) –Relationship between Development, Experience, and Challenge in the Performance of the Different Inquiry Components (in light of the Observation).....	224
3.3.3 Stage 3: Final Stage of the Inquiry Project (12 th Grade) – Relationship between Development, Experience, and Challenge in the Performance of the Different Inquiry Components (in light of the Observation)	236
3.3.4 overall picture of the Relationship between the Development, Experience, and Challenges in the Performance of the Different Inquiry Components throughout the 3 Stages of the Program	249
3.4 Comprehensive Summary of the Findings for the First Research Question.....	263
4. FINDINGS AND CONCLUSIONS FOR THE SECOND RESEARCH QUESTION.....	286
4.1 The Students’ Perception of the Differences between Activities in the Laboratory in the School Framework and the Research Physics Framework (a Learning Environment Focusing on Inquiry Projects).....	287
4.1.1 Quantitative Analysis – Degree of Difference between Activities in the Laboratory in the School Framework and the Research Physics Framework according to the Students (in Stage 2 and Stage 3 of the Inquiry Work).....	287
4.1.2 Qualitative Analysis – Description of Main Differences between the Research Physics Framework and Laboratory Activity in the School Framework (in Stage 2 and Stage 3 of the Inquiry Work)	289
4.1.3 Main Findings- Student’s Viewpoint of Main Differences between the Research Physics Framework and the Laboratory Activity in the School Framework	294

4.2 The Students' Attitudes about the Inquiry Process and the "Research Physics" Learning Environment (Particularly the Roles of the Students and the Teachers and the Learning Resources).....	301
4.2.1 The Students' Perception of the Aspect: Managing the Inquiry Work (in Stage 2 and Stage 3 of the Inquiry Work).....	302
4.2.2 The Students' Perception of the Aspect: Building Content Knowledge in the Inquiry Work (in Stage 2 and Stage 3 of the Inquiry Work).....	321
4.2.3 The Students' Perception of the Aspect: Teamwork in the Inquiry Work (in Stage 2 and Stage 3 of the Inquiry Work).....	326
4.2.4 The Students' Perception of the Aspect: Identifying with the World of the Scientific Researcher (in Stage 2 and Stage 3 of the Inquiry Work).....	333
4.3 The Students' Degree of Satisfaction with the Instruction of the Teacher-Mentor in the Research Physics Program	337
4.3.1 Stage 2 – Intermediate Stage of the Inquiry Project – Students' Degree of Satisfaction with the Instruction (Self-Reporting Questionnaire before the Submission of the Intermediate Report, 11th Grade)	337
4.3.2 Stage 3 – Final Stage of the Inquiry Project – Students' Degree of Satisfaction with the Instruction (Self-Reporting Questionnaire before the Submission of the Summative Report, 12th Grade)	341
4.3.3 Main Findings- Students' Satisfaction with the Instruction of the Teacher-Mentor during the Inquiry Work.....	345
4.4 Comprehensive Summary of the Findings for the Second Research Question	349
5. DISCUSSION	369
5.1 Discussion	369
5.2 Research Limitations	392
5.3 Suggestions for Further Research	397
6. REFERENCES.....	398

List of Figures

Figure 1:	A Model for Science – To Combine Conceptual understanding and Procedural Understanding (from Gott & Duggan, 1995)	12
Figure 2:	Recommendations to Combine Inquiry at a Variety of Levels, to Move Gradually on This Scale between Structured Inquiry and Open Inquiry (Sigron, M)	39
Figure 3:	Concurrent Strategy of Triangulation- Research Design: Qualitative and Quantitative and Mixed Approaches (Creswell, 2003)	86
Figure 4:	Report of Students on Considerable Experience in the Performance of the Different Inquiry Components in the Preparation Stage for the Inquiry Project (10 th Grade - N=27)	107
Figure 5:	Report of Students on Considerable Difficulty in the Performance of the Different Inquiry Components in the Preparation Stage for the Inquiry Project (10 th Grade - N=27)	107
Figure 6:	Report of the Students on the Considerable Experience in the Performance of the Different Inquiry Components in the Intermediate Stage of the Inquiry Work - the 11 th Grade (N=33)	112
Figure 7:	Report of the Students on the Considerable Difficulty in the Performance of the Different Inquiry Components in the Intermediate Stage of the Inquiry Work - the 11 th Grade (N=33)	113
Figure 8:	Report of Students on Considerable Experience in the Performance of the Different Inquiry Components in the Final Stage of the Inquiry Project (12 th Grade - N=34)	124
Figure 9:	Report of Students on Considerable Difficulty in the Performance of the Different Inquiry Components in the Final Stage of the Inquiry Project (12 th Grade - N=34)	125
Figure 10:	Reporting of Students on the Considerable Experience in the Performance of the Different Inquiry Components – Comparison between the Preparation Stage (N=27) and the Intermediate Stage of the Inquiry Project (N=33)	137
Figure 11:	Reporting of Students on the Considerable Difficulty in the Performance of the Different Inquiry Components – Comparison between the Preparation Stage (N=27) and the Intermediate Stage of the Inquiry Project (N=33)	138

Figure 12:	Reporting of Students on the Considerable Experience in the Performance of the Different Inquiry Components – Comparison between the Intermediate Stage (N=33) and the Final Stage (N=34) of the Inquiry Project	140
Figure 13:	Reporting of Students on the Considerable Difficulty in the Performance of the Different Inquiry Components – Comparison between the Intermediate Stage (N=33) and the Final Stage (N=34) of the Inquiry Project	141
Figure 14:	Reporting of Students on the Considerable Experience in the Performance of Additional Inquiry Components – Comparison between the Intermediate Stage (N=33) and the Final Stage (N=34) of the Inquiry Project	143
Figure 15:	Reporting of Students on the Considerable Difficulty in the Performance of Additional Inquiry Components – Comparison between the Intermediate Stage (N=33) and the Final Stage (N=34) of the Inquiry Project	145
Figure 16:	Overall Picture – Report of Students on the Considerable Experience in the Performance of Inquiry Components in Different Stages in the Program: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34) of the Inquiry Work	147
Figure 17:	Report of Students on the Considerable Experience in the Different Inquiry Components – Comparison between Preparation Stage (N=27) and Final Stage (N=34) of the Inquiry Work	148
Figure 18:	Report of Students on the Considerable Experience in the Performance of Different Inquiry Components – Comparison between the Stage between the Start of the Program (N=33) and the Final Stage of the Inquiry Work (N=34)	150
Figure 19:	Overall Picture - Report of Students on the Considerable Difficulty in the Performance of Inquiry Components in the Different Stages of the Program – Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34) of the Inquiry Work	151
Figure 20:	Report of Students on the Considerable Difficulty in the Performance of the Different Inquiry Components – Comparison between the Preparation Stage (N=27) and Final Stage (N=34) of the Inquiry Work	152

Figure 21:	Overall Picture - Report of Students on the Considerable Experience in the Performance of Additional Inquiry Components in the Different Stages of the Program – Intermediate Stage (N=33) and Final Stage (N=34) of the Inquiry Work	156
Figure 22:	Overall Picture - Report of Students on the Considerable Difficulty in the Performance of Additional Inquiry Components in the Different Stages of the Program – Intermediate Stage (N=33) and Final Stage (N=34) of the Inquiry Work	157
Figure 23:	Report of Students on Considerable Development in the Different Inquiry Components in the Preparation Stage of the Inquiry Project (10 th Grade, N=27)	167
Figure 24:	Report of Students on Considerable Development in the Different Inquiry Components in the Intermediate Stage of the Inquiry Project (11 th Grade, N=33)	171
Figure 25:	Report of Students on Considerable Development in the Different Inquiry Components in the Final Stage of the Inquiry Project (12 th Grade, N=34)	182
Figure 26:	Report of Students on Considerable Development in the Inquiry Components – Comparison between the Preparation Stage (N=27) and the Intermediate Stage (N=33) of the Inquiry Project	194
Figure 27:	Report of Students on Considerable Development in the Inquiry Components – Comparison between the Intermediate Stage (N=33) and the Final Stage (N=34) of the Inquiry Project	196
Figure 28:	Report of Students on Considerable Development in the Additional Inquiry Components – Comparison between the Intermediate Stage (N=33) and the Final Stage (N=34) of the Inquiry Project	198
Figure 29:	Overall Picture – Report of Students on the Considerable Development in the Different Inquiry Components in the Different Stages on the Inquiry Work: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)	200
Figure 30:	Report of Students on the Considerable Development in the Inquiry Components between the Preparation Stage (N=27) and the Final Stage (N=34) of the Inquiry Work	201

Figure 31:	Overall Picture – Report of Students on the Considerable Development in the Additional Inquiry Components of the Inquiry Work: Intermediate Stage (N=33) and Final Stage (N=34)	204
Figure 32:	Self-Reporting of Students on the Considerable Development/Experience in the Performance of the Inquiry Components, 10 th Grade (N=27)	215
Figure 33:	Relationship between Considerable Development and Considerable Experience in the Performance of the Different Inquiry Components – Representation of the Deviation from the Mean Frequency (Development 23.67%, Experience 62.96%) 10 th Grade (N=27) (Sigron, M)	216
Figure 34:	Self-Reporting of Students on Considerable Development/Difficulty in the Inquiry Components, 10 th Grade (N=27)	217
Figure 35:	Relationship between Considerable Development and Considerable Difficulty in the Performance of the Different Inquiry Components – Representation of the Deviation from the Mean Frequency (Development 23.67%, Difficulty 23.11%), 10 th Grade (N=27) (Sigron, M)	218
Figure 36:	Relationship between Considerable Development and Considerable Experience/Difficulty in the Performance of the Different Inquiry Components – Representation of the Deviation from the Mean Frequency (Development 23.67%, Experience 62.96%, Difficulty 23.11%), Stage 1 – 10 th Grade (N=27) (Sigron, M)	220
Figure 37:	Self-Reporting of Students of Considerable Development/Experience in the Performance of the Inquiry Components, 11 th Grade (N=33)	225
Figure 38:	Relationship between Considerable Development and Considerable Experience in the Performance of the Different Inquiry Components – Representation of the Deviation from the Mean Frequency (Development 28.68%, Experience 74.95%), 11 th Grade (N=33) (Sigron, M)	226
Figure 39:	Self-Reporting of Students on the Considerable Development/Difficulty in the Performance of the Inquiry Components, 11 th Grade (N=33)	227

Figure 40:	Relationship between Considerable Development and Considerable Difficulty in the Performance of the Different Inquiry Components – Representation of the Deviation from the Mean Frequency (Development 28.68%, Difficulty 13.65%), 11 th Grade (N=33) (Sigron, M)	228
Figure 41:	Relationship between Considerable Development and Considerable Experience/Difficulty in the Performance of the Different Inquiry Components – Representation of the Deviation from the Mean Frequency (Development 28.68%, Experience 74.95%, Difficulty 13.65%), Stage 2 – 11 th Grade (N=33) (Sigron, M)	230
Figure 42:	Self-Reporting of Students on the Considerable Development/Experience in the Performance of Inquiry Components, 12 th Grade (N=34)	237
Figure 43:	Relationship between Considerable Development and Considerable Experience in the Performance of the Different Inquiry Components – Representation of the Deviation from the Mean Frequency (Development 33.13%, Experience 78.62%) 12 th Grade (N=34) (Sigron, M)	238
Figure 44:	Self-Reporting of the Students on the Considerable Development/Difficulty in the Performance of the Inquiry Components, 12 th Grade (N=34)	239
Figure 45:	Relationship between Considerable Development and Considerable Difficulty in the Performance of Different Inquiry Components – Representation of the Deviation from the Mean Frequency (Development 33.13%, Difficulty 13.21%), 12 th Grade (N=34) (Sigron, M)	240
Figure 46:	Relationship between Considerable Development / Considerable Experience/Difficulty in the Performance of the Different Inquiry Components – Representation of the Deviation from the Mean Frequency (Development 33.13%, Experience 78.62%, Difficulty 13.21%), Stage 3 – 12 th Grade (N=34) (Sigron, M)	242
Figure 47:	Report of Students on the Considerable Experience in the Performance of the Inquiry Components of Group 1 in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)	250

Figure 48:	Report of Students on the Considerable Difficulty in the Performance of the Inquiry Components of Group 1 in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)	250
Figure 49:	Report of Students on the Considerable Development in the Performance of the Inquiry Components of Group 1 in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)	251
Figure 50:	Reporting of Students on the Considerable Experience in the Performance of the Inquiry Components of Group 2 in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)	252
Figure 51:	Reporting of Students on the Considerable Difficulty in the Performance of the Inquiry Components of Group 2 in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)	252
Figure 52:	Reporting of Students on the Considerable Development in the Performance of the Inquiry Components of Group 2 in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)	253
Figure 53:	Reporting of Students on the Considerable Experience in the Performance of the Inquiry Components of Group 3 in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)	254
Figure 54:	Reporting of Students on the Considerable Difficulty in the Performance of the Inquiry Components of Group 3 in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)	255
Figure 55:	Reporting of Students on the Considerable Development in the Performance of the Inquiry Components of Group 3 in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)	255
Figure 56:	Reporting of Students on the Considerable Experience in the Performance of the Inquiry Components of Group 4 in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)	257

Figure 57:	Reporting of Students on the Considerable Difficulty in the Performance of the Inquiry Components of Group 4 in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)	257
Figure 58:	Reporting of Students on the Considerable Development in the Performance of the Inquiry Components of Group 4 in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)	258
Figure 59:	Report of Students of the Degree of the Difference between Activities in the Laboratory in the School Framework and in the Research Physics Framework – In the Intermediate Stage (N=33) and in the Final Stage of the Inquiry Work (N=34) (Sigron, M)	288
Figure 60:	Report of the Students on Who Is Responsible for the Success of the Inquiry Project – Comparison of the Frequencies between the Intermediate Stage (N=33) and the Final Stage of the Inquiry Work (N=33)	303
Figure 61:	Report of the Students of the Degree of Responsibility for the Success of the Project of the Student and the Teacher-Mentor – Comparison of the Means between the Intermediate Stage (N=33) and the Final Stage of the Inquiry Work (N=33)	305

List of Tables

Table 1:	Different Levels of Inquiry Teaching, (+) Indicates Directions Given to the Student by the Teacher (Tamir, 1971)	36
Table 2:	Activities and Components of the Inquiry in Each Activity in the Learning Sequence of the "Research Physics" Program (Sigron, M)	71
Table 3:	Research Instruments relate to the Research Questions (Sigron, M)	99
Table 4:	Times of the Distribution of the Research Instruments and the Data Collection (Sigron, M)	101
Table 5:	The Main Difficulties that Arose from the Students' Reports in the Inquiry Components – Phrasing Questions/Goals, Drawing Conclusions, Oral Reporting of the Inquiry, and Building Content Knowledge (Sigron, M)	160
Table 6:	The Main Difficulties that Arose from the Students' Reports in the Inquiry Components – Locating Information Sources, Planning an Experiment, and Performing an Experiment (Sigron, M)	161
Table 7:	The Main Difficulties that Arose from the Students' Reports in the Inquiry Components – Data Processing and Written Reporting on the Inquiry (Sigron, M)	162
Table 8:	The Main Difficulties that Arose from the Students' Reports in the Inquiry Components – Using Technological Aids and a Computerized Laboratory, Building a Theoretical Model, Self-Regulation, Teamwork with the Partner, and Teamwork with Peers in the Broader Group (Sigron, M)	163
Table 9:	Main Aspects of Development Arising from the Students' Reports in the Inquiry Components: Phrasing Questions/Goals, Performing an Experiment, and Drawing Conclusions (Sigron, M)	206
Table 10:	Main Aspects of Development Arising from the Students' Reports in the Inquiry Components: Written Reporting on the Inquiry, Building Content Knowledge, Self-Regulation, and Teamwork with the Partner (Sigron, M)	208
Table 11:	Main Aspects of Development Arising from the Students' Reports in the Inquiry Components: Choosing a Topic and Using Technological Aids and a Computerized Laboratory (Sigron, M)	210

Table 12:	Main Aspects of Development Arising from the Students' Reports in the Inquiry Components: Planning an Experiment and Oral Reporting on the Inquiry (Sigron, M)	211
Table 13:	Main Aspects of Development Arising from the Students' Reports in the Inquiry Components: Locating Information Sources, Data Processing, Building a Theoretical Model, and Teamwork with the Peers in the Broader Group (Sigron, M)	212
Table 14:	Main Aspects of Development Arising from the Students' Reports in the Inquiry Component: Identifying with the World of Scientific Inquiry (Sigron, M)	213
Table 15:	Main Differences between Research Physics Framework and Laboratory Activity in the School Framework from the Student's Perspective (Sigron, M)	294
Table 16:	The Students' Perception of the Responsibility for the Inquiry Work in General and the Actual Learning Environment (N=33) (Sigron, M)	306
Table 17:	Quotes from the Interviews for the Question: "Who do you think has greater responsibility for learning and success of the project – the teacher-mentor or the student?"	308
Table 18:	The Students' Perception of the Degree of Independence and Initiative in General and the Actual Learning Environment (N=33)	310
Table 19:	The Students' Perception of the Planning and Organization of the Inquiry Work in General and the Actual Learning Environment (N=33)	314
Table 20:	The Students' Perception of the Coping with the Dynamism of the Inquiry and with Situations of Uncertainty during the Inquiry Work in General and the Actual Learning Environment (N=33)	317
Table 21:	The Students' Perception of the Building Content Knowledge in General and the Actual Learning Environment (N=33)	322
Table 22:	The Students' Perception of the Teamwork with the Project Partner in General and the Actual Learning Environment (N=33)	327
Table 23:	The Students' Perception of the Teamwork with the Peers in the Broader Group in an Inquiry Work in General and the Actual Learning Environment (N=33)	330

Table 24:	The Students' Perception: Identification with the World of Scientific Research in General and the Actual Learning Environment according to Students (N=33)	334
Table 25:	Degree of the Students' Satisfaction with the Teacher-Mentor's Instruction (11 th Grade)	338
Table 26:	Degree of the Students Satisfaction with the Teacher-Mentor's Instruction (12 th Grade)	341
Table 27:	Main Aspects in the Students' Satisfaction with the Teacher-Mentor's Instruction (Sigron, M)	346

Introduction

1. Project Field

Science Education, Physics laboratory, Inquiry Learning, Physics Inquiry

2. Subject Importance

The role of each and every generation, from time immemorial, is to train the following generation for the future. The nature of the social, economic, industrial, and technological changes presents the current generation with new challenges. The questions we face are as follows. What are the skills that the educational system must develop and inculcate? How do we prepare to ready the next generation for the coping with the new requirements in the job market? What do we need to do today so that our students, the citizens of tomorrow, can succeed and cope with the new requirements and the challenges that society, the economy, the industry, technology, and the career place before them? (Pessig, 2000).

For the purpose of coping with the challenges that these changes present us, the educational system must allow the students to develop their thinking and learning skills and to develop abilities of teamwork, encourage natural curiosity, provide an outlet for creativity, and promote their ability to act under conditions of uncertainty, a clear characteristic of the present era. This reality spurs the educational systems in many countries around the world, including Israel, to search for ways to adjust schools to the challenges of the 21st century (National Research Council, 1996; 2000; Pedagogical Secretary, 2008).

According to Salomon (2000), the task of the school of the 21st century needs to be different from its present task. The nature of the school educational task is, on the one hand, to engage in the teaching of contents, the ‘what’, and on the other hand, to inculcate skills of learning, the ‘how’, and in parallel to continue with the inculcation of social and cultural values. In his opinion, it is important to address the unique qualities that must be cultivated among the students who will finish their studies in a number of years, or in other words, to delineate the figure of the desired graduate. The cultivation of the desired graduate obligates the shaping of a certain learning environment that will allow him to cultivate the desired attributes.

The graduates of the educational system, the citizens of the future, need a high level of thinking ability, which will allow them to understand new knowledge independently, while implementing critical and creative thinking. This ability will help them adapt themselves to a changing reality and make reasoned decisions. The achievement of this ability among the students necessitates a change in the ways of instruction, learning, and assessment. The change entails the transition from learning that emphasizes repetition of information to meaningful learning, which emphasizes the in-depth understanding of contents and the abilities of learning and thinking (Pedagogical Secretary, 2008).

According to Benjamin (1989), in the future the workers will be required to have higher order thinking skills and knowledge will quickly become outdated. Therefore, the students of today, who are the citizens of tomorrow, must think critically, research, and know the scientific process. The process, which is in essence the actions of the scientist on his way to cope with problems, is no less important than the acquisition of a corpus of knowledge (Roberts, 2001). According to Kirschenbaum and Simon (1974), it is necessary to shift the main focus from the content to the learning methods. They maintain that it is not possible today to learn the quantities of knowledge and therefore it is necessary to change the emphasis from the content – from *what* to learn to the teaching methods, *how* to learn. This is the transition from the content to the process.

Barrow (2006) also asserts that it is necessary to reduce the quantity of knowledge that the student must remember and to encourage thinking skills and he must play an active part in the processes of research and problem solving. Thus the importance of active learning, both in the experimental dimension (the students themselves will undertake activities) and in the choice of contents will increase (Bybee, 2000). The goal of the teaching is no longer the transfer of knowledge but the development of a ‘thinking learner’ with self-direction. The emphasis in learning is no longer a concept of the memorization of the material but of investigation, use of knowledge, and construction of meaning. To achieve meaningful learning, which is the goal of this approach, the teacher needs to lead the student to active collaboration in the learning process. The teacher transforms from a source of knowledge to a mediator between the student and the knowledge, directing and guiding him in the learning process (Birenboim, 1997). To achieve this goal, the class environment must change, from an environment that encourages students to repeat facts to

an environment that encourages the students to take initiative and responsibility for the learning processes (Alberts, 2000; Gibson & Chase, 2002).

Learning through inquiry is based on this outlook of learning that promotes in-depth understanding, both in the contents and in the learning and thinking abilities. This way of learning requires the development of thinking tendencies and practices such as curiosity, precision, asking questions, multi-stage thinking, critical thinking, creativity, and experience under conditions of uncertainty (Branco Weiss Institute Website). In addition, learning through inquiry develops independent and active learning, which transfers the responsibility for the learning largely to the student and provides a place for initiative and coping with challenges, both on the part of the student and on the part of the teacher. This method of learning implements the cognitive strategies of the students in a process of problem solving and self-learning and inspires motivation to learn (Hativa, 2003). Inquiry-based learning is a way of meaningful learning, which suits the reality of the 21st century (Branco Weiss Institute Website).

In recent years, attempts have been made to teach science with greater emphasis than in the past on inquiry learning and the student's experience in inquiry, in different places in the world in general (NGSS 2013; Barrow, 2006; Bybee, 2000; Krajcik et al., 2000; NRC, 1996, 2000, 2012) and in Israel in particular (Kapach, 2014; Pedagogical Secretary, 2008; Hofstein et al., 2007; Langley & Alon, 2007; Zion et al., 2007; Zohar, 2007).

However, in Israel a gap has been created between the declarations on the importance of the teaching of inquiry and the implementation of the teaching in practice. Learning and teaching through inquiry is prevalent in the educational system in Israel, and it would seem that it is known and familiar. However, students and teachers who work in the inquiry approach report many difficulties and frustrations. Frequently the school adopts external indications of inquiry (such as submitting a work) and neglects the more essential characteristics of the inquiry (such as the learner is active in the building of his knowledge, creates insights in a variety of thinking strategies). Consequently, the main goal of the learning is distorted. In other words, most of the in-depth components of the inquiry learning have been given up and inquiry has a small part in the teaching, despite the agreement among researchers in the teaching of the sciences and teachers on the importance of inquiry and inquiry skills (Zohar, 2007).

In addition, learning through inquiry in the field of the teaching of physics in the high school is novel in Israel. In the teaching of physics in Israel, the laboratory constitutes 15% of the high school matriculation examination at the five units of study level. (It should be noted that high school matriculation examination in physics in Israel is divided into different levels: one unit of study, three units of study, and five units of study, when 5 units of study is the highest level.) The laboratory is one of the possible environments for the integration of inquiry in the teaching of physics. For all the laboratory lessons in physics of a certain class in the high school in Israel there is a chance of about 95% that all the laboratory activities will be conducted in the traditional teaching approach (the datum is current for the summer of 2013 and was given by the subject supervisor of physics on the basis of the data of Administration and Information and Communications Technology and Information Systems in the Ministry of Education).

According to this approach, laboratory activity is intended to confirm a theoretical relation that the student learned previously in class (Etkina, Van Heuvelen, & Mills, 2002), and therefore this approach is called the confirmatory laboratory. The traditional teaching approach, the confirmatory laboratory, operates according to a closed guide written ahead of time by the teacher, who guides the students step after step, until they reach the expected answer, in the framework of time of two to three lessons (Domin, 1999). Educators criticize this approach, since it does not support the achievement of main goals of laboratory work, such as the development of high order thinking skills (for instance, asking questions and planning experiments), providing an opportunity for independent work that enables the students to study questions that interest them, the possibility of making mistakes and learning from these mistakes, the exposure to select aspects of the ways of work of scientists, and the understanding of the place of the laboratory experiment in the research. These goals can be achieved through activities in an inquiry-based laboratory (Kapach, 2014).

To adjust the laboratory teaching to the role of the experiment in the real world of physics, the teachers must integrate in the studies of the laboratory the inquiry based teaching approach (Dewey, 1910; Etkina, Van Heuvelen & Mills, 2002). One of the conclusions from the research undertaken recently by Dr. Kapach (2014), *From Laboratory Teaching in the Cookbook Approach to Laboratory Teaching in the Inquiry-Based Approach in the Studies of Physics in the High School: Professional Development of Teachers*, is that physics teachers

acknowledge the importance of the promotion of inquiry skills in the classroom but most do not engage in it routinely. The tension between the extensive engagement in the way of inquiry and the difficulties entailed by the implementation of this way require therefore in-depth clarification. Learning through inquiry is an ongoing challenge (Zohar, 2007). In the inquiry laboratories there is the potential to promote meaningful learning among the students, to increase the depth of their understanding of the scientific concepts and the understanding of the nature of science (Tobin, 1990; Lunetta, 1998; Hofstein & Lunetta, 2004), and the inquiry is a main part in the way to achieve the goals of science education. Hence, the Department for the Instruction of the Sciences is committed to the research of this field of learning through inquiry.

4. Project Importance

Committees of experts have called for the incorporation of scientific inquiry into the school since the start of the 20th century (Dewey, 1938) and continue to call for it today (NRC, 1996, 2000; NGSS 2013). In particular, they call to allow students to attempt the process of the search under conditions of uncertainty and the process of characterization and explanation of a phenomenon in the real world, so as to give the students the tools necessary for integration into the advanced society of the 21st century.

The learning method of inquiry is at its beginning in the State of Israel and mainly in the knowledge realm of physics. In Israel, only about 5% of the laboratory lessons in physics combine activities based on the inquiry approach, since most of the teachers who teach physics in the high school are not experts in teaching using inquiry (Kapach, 2014). The desire to inculcate in the graduates of the physics study program the tools necessary for their integration into the advanced society of the 21st century has dictated the need to build a unique program called ‘Research Physics’ with the support of the developers and expert teachers. This program enables the students to attempt inquiry skills in different types of activities, which offer a variety of levels of research. Thus, the students can learn and research in some in-depth manner topics from the curriculum, get to know new topics, and develop a variety of skills acquired through inquiry (Draft for the Subject Committee towards Discussion of the Research Physics Program, written by the program authors).

The research proposed here will be held in the framework of the 'Research Physics' Program (see more about the program in the chapter of the Review of the Literature), which will constitute a leading program from which the boundaries of inquiry will be derived – ways of instruction, contents, planning, ranking, and evaluation. This program is still being researched. In general, information is lacking about the influences of the inquiry on the learning among high school students. In the background of the research there is the recognition, on the one hand, of the importance of in-depth research practices as learning goals for physics students in the high school and on the other hand, of the fact that in reality it is very difficult to develop such practices in schools because of the many constraints existing in a system oriented on standardized tests. This is a system that does not leave time for the lengthy work processes that characterize research, with a teaching workforce possessed of knowledge focused on the contents of the curriculum, which mainly addresses known and short problems and not open-ended problems that call for research, and with sparse technical equipment and support resources.

Given a framework in which the constraints are removed and in which the student can perform long-term inquiry, what is its added value? What experiences and challenges does such a framework offer the students? In which inquiry components will the students experience significant development? How will the students perceive this learning environment that focuses on inquiry?

Accordingly, this research study examines these questions in the framework of the 'Research Physics' Program, in the framework of a new subject in the education system in Israel (in the high schools), which attempts to provide a response to these constraints. This is a three year subject (from the tenth grade through the twelfth grade), in which students perform inquiry in physics at a steadily increasing scope, which concludes with a research project (see the list of projects of the students in the appendix 2.2) that lasts about two years in the eleventh-twelfth grade, so that the time limit has been removed. A framework supporting the professional knowledge of the instructors and a framework of individualized assessment were built, and the program is held in advanced laboratories for students in regional centers. When the program has adopted the pedagogical principles of design of the learning through inquiry and apprenticeship – learning through experience in authentic tasks in a rich context, with teamwork of the novice (student) and the expert (instructor).

The assumption is that the teacher does not constitute a limiting factor in the choice of the inquiry approach and has the training and desire to engage in open-ended inquiry. In other words, the endeavor is based on relatively great freedom of action, in terms of the constraints of time, equipment, and teaching force.

The research followed up after the students' perception of their experience, challenge, and development in the different inquiry practices in different stages in their inquiry work, so as to present the relationship between the development, experience, and challenge that the students experienced in the performance of the different inquiry components in the different stages of the program (see chapter 3). Moreover, the research followed up after the students' perception of the inquiry process and the 'research physics' learning environment that is focused on inquiry (in particular, the roles of the student and the teacher, the learning resources and the support that they believe they received in the framework of the program and their satisfaction with it) and how this learning environment contributes to them in the performance of the inquiry work (see chapter 4). When the research population consists of students who learn physics studies in high school and who participated in the Research Physics Program in the Davidson Institute in the Weizmann Institute, for three years (tenth to twelfth grades).

The research approach was based on the students' self-reports (questionnaires and interviews) throughout the main milestones during their inquiry work (preparation stage, intermediate stage, and final stage of the inquiry work) and on observations in the program sessions. This self-reporting was examined in light of the observation in the field – the way in which the intervention of the program was carried out, and according to the investigation findings possible recommendations are produced for the design of the framework of the 'Research Physics' program and the consequences of the research (see chapter 3.4, 4.4 and chapter 5). In addition, from the research results can derive benefit in the search for effective educational methods for the promotion of the inquiry topic and thus encourage teachers of physics to combine learning through inquiry in the framework of laboratory studies in physics. This is to assimilate the inquiry in the teaching of physics and in this way to reduce the gap that is created between the declarations about the importance of inquiry teaching and the implementation of the teaching in actuality. Therefore, the research results may contribute to the knowledge existing today on the characteristics of learning and teaching through inquiry in general and on the teaching of physics in particular.

1. Knowledge in the Research Field – Review of the Literature

This part of the review of the literature presents the theoretical background about two main topics of this work. The first topic is: What is the Inquiry Process? Inquiry in general and in the Teaching of the Sciences in particular (chapter 1). This chapter will include a historical look at the development of the idea of ‘inquiry’, the components of Scientific Inquiry, the teacher’s level of involvement and the student’s degree of independence in every component, change of the perception of the role, both of the student and of the teacher, in the performance of the inquiry process, the different levels of inquiry and the advantages and disadvantages on every level, and the challenges and the difficulties in teaching and learning through inquiry. The second topic is the role of the laboratory in the teaching of the sciences and in the teaching of physics in Israel and the combination of inquiry activities in it (chapter 2). In chapter 3 we focus in the framework of a field research on ‘Research Physics’ program, in which the goals and structure of the program will be described.

1.1 What Is the Inquiry Process? Inquiry in general and in the Teaching of the Sciences in particular

1.1.1 The Historical Look at the Development of the Idea of ‘Inquiry’

Much has been written about inquiry, and there are many ways to interpret and understand it. On the basis of the dictionary definition of Even Shoshan (Even Shoshan, 1969), it is possible to define the process of inquiry as a "*process that leads to the examination and in-depth study of an issue so as to discover what is embodied in it*". In other words, this is a process in which people search to discover, know, and even understand something that is not known (to us), something deep and hidden from our understanding or our knowledge of the researched topic. To discover this, it is possible to use different ways and diverse sources of information, through which we will learn what the researched issue includes or entails (from the website of the Branco Weiss Institute).

The concept of inquiry was first introduced into the field of education by John Dewey (1938), the great American philosopher. Dewey defined inquiry as a process in which the undefined and the unknown becomes, in a directed and controlled manner, a uniform and clear whole. It is a process of seeking a solution to the problem, which is not well defined, focusing on the problem and design ways to solve it. In his opinion, inquiry is a way of learning that excels in the maximum openness and flexibility and in the minimum instruction and guidance.

Dewey (1938) included a number of stages in the learning of inquiry. In the first stage, there is the feeling of the problem. The learner is in a situation that entails problems but he must feel the problems. The student must encounter difficulty that serves as a motive for the continuation of the engagement in the researched topic. The next stage is the definition of the problem. The student must define the problem before he begins to search for its solution. The last stage is the search and the solution. Following the raising of hypotheses, the student must examine the hypotheses and choose the way that leads to the solution. In fact, it is a process of seeking a solution to the problem that is not well defined, focusing on the problem and design ways to solve it (Barrow, 2006; Dewey, 1938).

Dewey (1910) addressed three aspects of meaningful learning: the acquisition of implementation of skills, the understanding of the way in which knowledge is created (the nature of science), and the understanding of essential topics of content. He maintained that meaningful knowledge cannot be taught on its own. Knowledge is not only the absorption of information but also a form of intelligent implementation of information. Only by taking part in the creation of knowledge, in other words, active participation, is it possible to enable understanding of the way in which people know.

More explicitly, Dewey saw inquiry as the asking of a question and the search for valid ways to answer it, through the implementation of thinking on a higher level. Learning through inquiry enables the development of rational, creative, critical, and reflective thinking about the topics of learning. This way of learning needs to be combined in the regular curriculum. Learning through inquiry is an ongoing process of many years, which needs to be started already in the early stages of education and to continue until the end of secondary school, through the adjustment to the students' abilities at the different stages (Pedagogical Secretary, 2008). At the beginning of the 1960s, Schwab (1960) proposed a

change in the method of instruction of science since scientists themselves no longer address science as facts that must be verified but as facts that must be researched. According to Schwab (1962), 'science as inquiry' should be taught through inquiry. In this way, the student experiences the search for and definition of the problem and copes with the problem through the search for ways to solve it, through the planning and performance of an experiment. There are many advantages of learning through inquiry: learning through inquiry allows the student to experience 'being a scientist'. In this way, he learns about himself and examines his attitude towards science. In addition, in this way it is possible for the learner to express creativity, originality, and curiosity. Therefore, Schwab maintains that it is necessary to express inquiry in the teaching of sciences.

According to the National Research Council (1996), inquiry in science addresses a variety of ways in which a scientist learns about the essence of nature and the ways in which he offers explanations on the basis of evidence that he collects during his work. Learning through inquiry includes activities through which the students develop knowledge and understanding about scientific ideas and about the way in which the scientist learns about the essence of nature.

Bybee (1997), addressing the standards that were determined (National Research Council, 1996), maintains that the emphasis in the study of science needs to be on the cognitive abilities and the development and improvement of the skills on the higher thinking levels. According to these standards, the reference to inquiry is in two aspects:

1. Inquiry as the understanding of content, in which the students are given the possibility of building concepts and models and giving meaning to some idea so as to explain the phenomena they observe.
2. Inquiry in the sense of skills and abilities (Bybee, 2000). Inquiry as technique, which addresses inquiry as a technique through which certain scientific content is learned (Rutherford, 1964). In the category of skills and abilities, Bybee (2000) includes the following skills: asking questions, forming hypotheses, planning and performing scientific experiments, phrasing explanations and scientific reasoning.

Hence, the process of inquiry is a process that requires on the one hand the in-depth understanding of the scientific topic and on the other hand the understanding and ability of analysis of a constellation of data obtained following the inquiry process. Therefore, the engagement in inquiry requires reference to the two components.

1. Conceptual understanding. This includes the meaning and nature of the field of knowledge. This part addresses the contents, main ideas, laws, principles, and theories related to the researched topic. The teaching of the corpus of knowledge, which focuses on knowledge, facts, and theories, is obvious, learned, and expressed in the curricula and textbooks,
2. Procedural understanding. This addresses the way in which the information is collected, analyzed, examined, and interpreted. The teaching of procedure is related more to the development of skills that will allow the student to cope with the way of data collection, organization, and analysis in a meaningful manner. The procedure is the action strategy of the scientist, which also includes the ideological basis for the scientific proofs. To examine a scientific proof, it is important to understand the way in which the information is collected, how it is analyzed, and to what extent it is reliable and valid. It is necessary to understand the possible interpretations of the given information and its boundaries. The teaching of the procedure is neglected relative to the teaching of the body of knowledge (Gott & Duggan, 1995; Roberts, 2001).

The researchers Gott and Duggan (1995) built a model (Figure 1) in which the relationship between information and teaching sciences is re-examined. The starting point of this model is that scientific thinking is coping with a problem when the way to solve it is inclusive and leads to the examination of the entirety of the data.

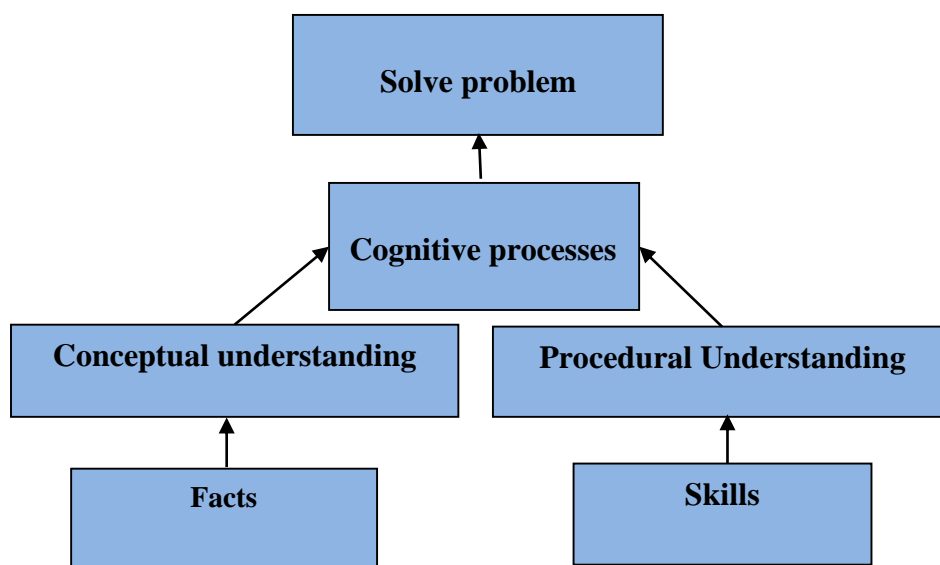


Figure 1: A Model for Science – To Combine Conceptual understanding and Procedural Understanding (Gott & Duggan, 1995, p.30)

The implementation of this model to the field of the teaching of the sciences means that in the teaching of the sciences it is necessary to address the two components: on the one hand the understanding of the contents and on the other hand the understanding of the methods through which different scientific questions are examined. Moreover, it is necessary to strive that equal weight is given to the two components: teaching aimed at the understanding of the body of knowledge, teaching aimed at the understanding of the procedure (Roberts, 2001; Roberts & Gott, 1999, 2000; Gott & Duggan, 1995).

The understanding of the procedure has characteristics different from those of the understanding of the body of knowledge: the understanding of the procedure is general and can be implemented in many areas, not necessarily in the field in which it is acquired, while the understanding of the body of knowledge includes specific content areas (Roberts, 2001). Research studies can be performed in different areas and in different ways, but they all have similar characteristics based on the same ideological format – and that they need to teach. Hence, there is considerable importance to the teaching of the procedure (Roberts, 2001; Roberts & Gott, 1999, 2000; Gott & Duggan, 1995). It is important to emphasize that the integration of the scientific inquiry process in teaching does not put the processes instead of the contents. The inquiry emphasizes the processes so as to go into greater depth in the contents and to make them into knowledge that is meaningful for the learner (Ben David, 2012).

The innovation is the emphasis given to the teaching of ‘procedural understanding’. The procedure should be taught so that the student will understand it. To understand what the procedure is and to go in-depth as much as possible in the teaching of the procedure, the following chapter discusses the components required during the performance of scientific inquiry, their meaning, and their importance.

1.1.2 Components of Scientific Inquiry

The components of learning through inquiry are many and diverse. Lunetta and Tamir (1979) divided four main skills:

1. Planning. Identification and formation of the inquiry problem, phrasing of the hypothesis with prediction of the outcomes, and planning observation or experiment suitable for the research of the specific problem. Planning the experiment includes the identification of the variables and the isolation of the variables.
2. Performance. Performance of qualitative/quantitative observations. Use of relevant tools for the process of the experiment according to planning and documentation of the results.
3. Analysis and interpretation. Processing of the results, organization of the results on the graph, if possible, finding of quantitative and qualitative relationships, and explanation of the relations found. Reference to the degree of precision of the results, awareness of the experiment limitations, suggestion of generalizations or a model, and formulation of a new problem that arises from the student’s results and conclusions.
4. Implementation. The student’s prediction ability, on the basis of the inquiry results, formulation of a new hypothesis, and continuation of the inquiry.

The process of scientific inquiry includes a number of main and necessary components, such as, for example, those detailed in the document ‘Assimilation of the Degree of Inquiry in the Educational System in Israel’ (Pedagogical Secretary, 2008) and from the articles of Krajcik et al. (2000), Etkina & Van Heuvelen (2007), Hofstein et al. (2007) and Ben David (2012):

- Choice of the topic – identification of the problem/phenomenon and recognition of the background (existing knowledge)
- Asking questions and asking inquiry questions
- Positing a hypothesis

- Inquiry constellation – process of the planning and performance of the way of the inquiry action (such as planning and performance of an experiment or observation)
- Processing the findings – treatment and organization of the results, such as collection, processing, representation, analysis, and comparison to sources
- Drawing conclusions
- Presentation of the inquiry process and its products
- Assessment of the inquiry and reflection

The aforementioned list of components is a basic and general list and it is possible, of course, to add elements. The inquiry can be a whole process, which includes all the components, or a modular process that enables the focus on individual parts of the full inquiry (Pedagogical Secretary, 2008; Rozenfeld & Flik, 2002). These components do not necessarily express chronological order. In actuality, the inquiry process is not necessarily linear but is composed of stages with reciprocal interaction and the transition between them is network-like. The formation of the inquiry question, for example, is a dynamic process and its formulation can change with the advance in the work stages. Often the students return to certain components, skip a component, and perhaps reach it at a later stage (or not at all). There are also components that strongly depend on what is done beforehand and cannot exist if a previous component is not done. Therefore, the term ‘components’ is used, and not the term ‘stages’, since the word ‘stages’ hints at a regular and necessary order. It is possible and desirable to work with the students on the repetition that is sometimes required of certain components in the inquiry process (Krajcik, Blumenfeld, Marx & Soloway, 2000; Etkina & Van Heuvelen, 2007).

Inquiry learning is an educational approach with the goal of developing an independent learner. The principle in this teaching is that the students are not presented the information intended for the learning in an explicit manner. Instead, the teacher creates an intellectual and social atmosphere, in the framework of which the learner has responsibility and control over the learning process. In this way, the students plan by themselves how to identify and achieve information, collect data, phrase by themselves the questions and the rules and laws according to which they will act, and determine themselves their pace of progress and the ways of learning (Hativa, 2003). For the students to cope with this complexity, the teacher’s help is required (Chinn & Malhotra, 2002). The teacher’s level of involvement and the student’s independence in every inquiry process mentioned above will be described in the following section.

1.1.2.1 Meaning and Importance of the Different Components in the Inquiry Process and Teacher's Level of Involvement and Student's Degree of Independence in Every Component

Many think that students will understand 'science' through 'doing science'; or in other words, performing inquiry activity. However, Bell, Blair, Crawford, and Lederman (2003) found in their research that most of the students who engage in inquiry activity, under the guidance of scientists, improved negligibly their understanding of the scientific topic and the process of inquiry they addressed. Hence, the inquiry activity is not enough to learn the topic; it is necessary also to learn the inquiry method and its components. Learning skills do not develop spontaneously for most students. They should be taught explicitly (Zohar & Nemet, 2002). The added value of the teaching of the inquiry components, according to Ogens (1991), is the increase of the chance to develop positive attitudes towards science among the students.

This chapter details, alongside the meaning and importance of all the components of scientific inquiry, the teacher's level of involvement and the student's degree of independence in the component. The teacher-mentor must examine the knowledge required of the students in every stage of the work and decide (in light of what is required and in light of their age, experience, and learning goals) which concepts and skills should be inculcated in them and the degree of support and accompaniment of the students (from the Branco Weiss Institute Website: Inquiry Process).

Choice of Topic: Identification of the Phenomenon/Problem and Knowledge of the Background (Existing Knowledge)

First, the learner must choose the 'supra-topic' or an interesting problem or the area in which the inquiry will be performed. It is desired that the inquiry topic be relevant to the student's life or inspire the student's personal interest (Harpaz, 2000). It is important to remember that students need instruction and direction when they search for a real problem to solve and to research (Markham, 2011). After the choice of the topic/problem, the student must recognize the background of the topic. This component includes the collection, organization, and presentation of existing knowledge. In this stage, what is

known on the field and on the certain topic that the inquiry addresses is examined. This is not a summary from books or other sources of information but an intelligent merger of information, which entails the examination of the relevance and the quality of the information sources. The background must be related to the topic of the inquiry and to the inquiry question and engage in what is known before the research is performed (Pedagogical Secretary, 2008).

This component enables us to focus on the topic and allows new learning. If we were not to do this step, then it would be harder to find something that interests us. We would not know what was done already and what should be researched so as to discover new things and we could not begin to work on something specific and we would lose direction. Hence, it is not possible to research without the choice of a topic, and it is greatly desired to know the background of the chosen topic (Branco Weiss Institute Website: Inquiry Process).

Generally this is the stage that begins the research, but it can continue and be performed throughout all the stages. Since the students tend to address this part separately from the core of the work (the research question and the answer to it), it is important to understand that the inquiry questions are always connected to previous knowledge collected and presented in the field and that the inquiry question can change following new information to which the students were exposed (Pedagogical Secretary, 2008).

The tasks of the teacher-mentor in this stage are to instill tools for the choice between interesting/possible issues, to propose a variety of possibilities of topics, to enable personal initiative in the choice of the topic, and to clarify along with the student whether he has access to the relevant material, to create interest and curiosity, to show a variety of ways for the collection of information (books, articles, Internet, databases, experts in the field), to teach ways for the examination of the reliability of the information sources, to guide and help in the clarification of the student's personal objectives regarding the research process, and to enable the student time for deliberation and conversation related to his deliberations in the choice of the topic. (The tasks presented here were raised by teachers on the basis of their work: Branco Weiss Institute Website: Research Process, Spector-Levy & Shartz, 2001; Rozenfeld & Flik, 2002).

Asking Inquiry Question

Asking questions is the key to active and meaningful learning and therefore constitutes an important component in the process of inquiry in science. Asking questions helps us understand the world and build meanings from data and information (Chin, 2004). A document published by the NRC (National Research Council, 2012) notes that asking questions constitutes an important component of scientific literacy, is essential for the development of scientific thinking skills, and helps the asker be a critical and thinking citizen regarding scientific knowledge – even the non-scientist.

A review of articles on the skills of asking questions by Chin and Osborne (2008) found that, in the aspect of learning, the questions asked by the learner can increase motivation and interest by inspiring curiosity, can focus the learning, can motivate the building of knowledge through the linkage of new ideas to previous knowledge, can encourage discussion and conversation, and therefore can develop quality of discourse and discussion in the class and help perform the self-evaluation of the understanding. In addition, in the aspect of the teaching of science it was found that the questions asked by the students can help the teacher assess the learners' understanding and thinking during the learning, inspire open inquiry beyond what is learned, evaluate high thinking abilities, and induce critical feedback on the learning.

It is very important to ask the inquiry question in the entire process of inquiry. The inquiry question focuses the investigation and influences the scope of the inquiry (Branco Weiss Institute: The Inquiry Process). In other words, the question must be the starting point of the entire research, since the student is intended to answer it. It is the basis for the hypothesis, for the collection of information, for the processing of information, for the research method, and for the shaping of the answer. It is also necessary to focus on the main place of the question in the summary of the research; it must be the axis around which the summative performance revolves. The research question determines the fate of the research, and therefore it is necessary to choose it carefully. If the question is found during the research to be unsuccessful in the student's opinion and there are convincing reasons for this, then it should be changed for another question (Harpaz, 2000).

According to Harpaz (2000), a good inquiry question is an intelligent question, phrased simply and productively. The scientific research question should be phrased concisely and clearly, if possible linking between two variables (dependent variable (influences) and independent variable (influenced)) (Ben David, 2012). Sometimes students tend to ask poor questions, since they are afraid that they can be answered without any great effort or since their imagination does not allow them. In contrast, some students choose a question that is too 'rich' and unpractical, a question that cannot be answered in the framework of the given time and means (Harpaz, 2000). Therefore, the inquiry question needs to be focused, leading the researcher in the direction he wants to go. It is forbidden for the question to go into too many fields, which will lead the student to many and unnecessary directions of investigation and thus will complicate the research work (Harpaz, 2000; Krajcik, Czerniak, & Berger, 1999).

In addition, according to Harpaz (2000), the inquiry question needs to interest the researcher, must be relevant to him, and must spark his curiosity. Students tend frequently to adopt questions that do not interest them, so as to satisfy the desire of the teachers-mentors or for other reasons. Therefore, it is not a trivial manner and it is necessary to ascertain that the question indeed interests the researcher. When students engage in the research, the research questions must have benefit and relevance to the students; otherwise the learning will be less meaningful (Barrow, 2006).

Therefore, it is not possible to conduct significant inquiry without an inquiry question. We will not know whether the answer we obtained succeeded in promoting our learning. We will not know whether what we found is meaningful, innovative, and promotes our learning (Branco Weiss Institute Website: Inquiry Process). In addition, if we do not ask an inquiry question, then we will not know exactly what we want to know. We may investigate very broad and unfocused things or very narrow things with barely any potential for true inquiry. The goal of the question is to help the learners focus on the research question as a basis for the continuation of the work (Krajcik, Czerniak, & Berger, 1999).

The asking of the inquiry question is not trivial. It entails all of the difficulties of the asking itself. Here a decisive stage in the work of the teachers-mentors begins (Harpaz, 2000). As we rise in the age group, we generally find that in the traditional class the role of asking questions is shifted to the teacher and that questions intended to examine whether and how

the teacher's statements or what is written in the book were internalized by the students. Therefore, a main challenge for the teachers in the high schools who are interested in promoting inquiry in the class is to overcome the tendency of the students to be passive learners relative to the asking of questions (Edwards, 1997). To encourage the students to ask questions that will be meaningful to the motivation of the learning, a class culture is required that esteems and respects good questions and provides opportunities to refine questions and to diversify strategies for teaching the skills (National Research Council, 2011).

Chin (2004) proposes to allocate time to the asking of questions during the learning in the class and to use a variety of strategies to encourage the students to ask, including providing adequate stimulus in the opening of the topic or during the inquiry activity, supply of guiding questions, and creation of social climate in which the students will feel comfortable to ask questions. Chin and Osborne (2008) maintain in the context of the inquiry process that research studies show that most of the questions proposed by students do not lead directly to the inquiry process. However, the teacher's help can lead to the translation of these questions into questions that lead to investigation.

In addition, during the research many students tend to return to the school writing to which they were accustomed – They forget the question and begin to 'summarize the material', 'to fill up the notebook'. In this case, the teachers-mentors must bring the students, again and again, back to their research question and not allow it to disappear from the agenda (Harpaz, 2000). The teacher-mentor's task in this stage is to inculcate skills of asking questions in general and in the field of knowledge in particular, to define what the inquiry question is and how it is asked, to stimulate and encourage the asking of questions, and to guide the students in the choice of the inquiry question at the scope suited to their inquiry work (Branco Weiss Website; Inquiry Process; Rozenfeld & Flik, 2002; Spector Levy & Shartz, 2001).

To summarize, the skill of asking questions has a main role in the motivation of the learning process in general and in inquiry in particular. Teachers have a main role in the development of the students' ability to ask questions in general and in the guidance of the asking of an inquiry question in particular. For this purpose, it is necessary to equip the students with the knowledge and tools for the building of a discourse culture in the class that encourages the asking of questions and with teaching strategies that have the goal of helping students be skilled in asking questions (Kapach, 2014).

Positing Hypotheses

A hypothesis is the formulation of a possible answer to the research question or the giving of a possible explanation to a phenomenon (there may be more than one hypothesis). The hypothesis needs to rely on existing theory/previous knowledge/certain laws/familiarity with similar phenomena, and it must clarify what the researcher intends to perform and to examine (Ben David, 2012).

According to the curriculum of the structure of an inquiry laboratory in chemistry (Department for Sciences – Chemistry, 2016), a hypothesis needs to be suited to the inquiry question chosen and to the experiment that will be planned, explained, and reasoned on the basis of knowledge from the relevant and correct science and phrased clearly and pertinently.

A research hypothesis in the field of the exact sciences is one of the scientist's 'work tools'. The hypothesis links between the theory and the experiment/observation. In many cases, on the basis of the experiment/observation it is possible to refute or confirm the hypotheses and thus to promote the knowledge on the different phenomena of nature (Pedagogical Secretary, 2009).

According to Lawson et al. (1991), in the first stage, the raising of the hypotheses, the student who attempts to explain the phenomenon that is 'researched' in the class proposes his hypotheses. These hypotheses are based on the previous perceptions that exist in him at the beginning of the learning process. The student clarifies to himself the nature of these hypotheses, while phrasing them precisely. Then he examines the implications of his ideas, through their phrasing in the form of an inference. The inference is translated in terms of experiment and then the variables are defined precisely. If we act on variable X (defined and measurable), then variable Y (also defined and measurable) will be influenced. In the final stage, the student will reach on the basis of the experiment's findings conclusions on the validity and reasonableness of his hypotheses. Since the student's hypotheses derived from his prior perceptions before the performance of the experiment, the refuting of the hypothesis or the discovery of imprecisions in it will lead him to the re-examination of these perceptions and the way for the desired conceptual change will be opened.

The component of the proposal of the hypotheses helps us focus the research on one possible answer and can also influence the choice of the research instrument. However, the hypotheses may bias the discovery and we may miss additional answers that perhaps are not initially thought about. Hence, it is possible to engage in inquiry also without explicitly hypothesizing hypotheses. Frequently we are not aware of the hypotheses that guide the investigation but they do exist. If we do not posit hypotheses, then we will find ourselves searching for different answers in too many ways and the work can take longer (Branco Weiss Website: Inquiry Process; Rozenfeld & Flik, 2002).

Schwab (1962) adds that the ability to offer a productive hypothesis in the research framework depends on the researcher's previous knowledge and also on his ability of imagination and creativity. Indeed, many teachers invite the students to posit hypotheses but guide this stage in only a technical and formal manner, without remembering that it is necessary to act intentionally to encourage the students' creativity in the process of the positing of the hypotheses.

The task of the teacher-mentor in this stage is to inculcate the concept of the hypothesis and the formulation of the hypothesis accepted in the field of study, to direct the student that the hypothesis addresses the research question and to examine this, to differentiate between a hypothesis and a guess, to identify whether the student has implicit hypotheses about the researched question, and to examine the extent to which the hypothesis can be confirmed or refuted (Branco Weiss Institute Website: Inquiry Process; Rozenfeld & Flik, 2002; Spector Levy & Shartz, 2001).

The Research Design – The Process of the Planning and the Performance of the Way of Action of Inquiry

The research design is a part of the inquiry work, which describes the way in which an answer to the research question is given. In this component, the methods and the tools used to collect the data are described, with the goal of answering the research questions (Pedagogical Secretary, 2008). The process of the planning of the way of scientific inquiry entails the implementation of a number of thinking strategies. First, it is necessary to choose the way suited for the examination of the scientific research hypothesis – planning and performance of a directed observation or a scientific experiment. A directed

observation is supposed to reflect the true situation in nature, but it is not possible to control the factors that influence the researched phenomenon (to isolate variables). In a directed observation, data of factors defined ahead of time in the research question are collected, through means and at times determined beforehand. In other words, a directed observation obligates prior and meticulous planning of the objects of the observation, through the measurement of the factors, the means of the measurement, and the recording, the definition of time and place (seasons, hour, frequency). In the observation, the researcher does not intervene in the phenomenon but documents it as it is, precisely and objectively to the extent possible, through the senses and/or quantitative measurements through technological devices. In a scientific experiment, the researcher intervenes in the phenomenon, he changes only one certain factor in a controlled manner, when he maintains the values of the rest of the factors constant (isolation of variables), so as to examine the influence of the certain factor on the researched phenomenon. The isolation of variables enables the researcher to negate alternative explanations of the experiment results and grants validity to the experiment conclusions. In addition, to negate possibilities of randomness of the experiment results and/or mistakes of performance/measurement, it is necessary to repeat the experiment a number of times and under the same conditions. Obtaining similar results in all the cases will increase the reliability of the conclusions that will be drawn on the basis of these results (Ben David, 2012).

According to Roberts (2001), the technical processes of the performance of an experiment should not be addressed as if the student who performs them also understands them from the very performance of the experiment. The understanding of the procedure is the understanding of the ‘thinking behind the doing’ and not the technical understanding of the doing or the performance itself. In the teaching and learning of the ‘procedure’ it is necessary to understand, emphasize, and reflect that the collection of the data and the scientific proofs are not a series of technical actions but a field in its own right that is based on the ideological and theoretical infrastructure. This infrastructure should be understood and taught so as to allow the student to understand the nature of the scientific proof and actions of the scientist.

The inquiry process will not be complete without findings collected so as to examine the hypothesis or so as to prove/refute the inquiry question. If we do not perform the research (it does not matter in what way), then we will not find facts/data/information about the question we asked and we cannot draw closer to the answer, we cannot confirm or refute our hypotheses, and we cannot draw conclusions or establish them (Branco Weiss Institute Website: Inquiry Process). Therefore, this part requires being consistent regarding the research question; or in other words, it must connect in a direct and logical manner to the research question and be as detailed and clear as possible (Pedagogical Secretary, 2008).

The tasks of the teacher-mentor in this part are to instill accepted ways of inquiry in general and in the field of knowledge in particular, to instill concepts according to the research type (a number of examples are as follows: quantitative research, qualitative research, dependence between variables, independent variable, dependent variable, control, repetitions, interview, survey, comparison), to instill skills or tools required for the performance of the chosen research type, to bring to the awareness the considerations in the choice of the inquiry method, to direct to the possible and suited inquiry approach in the field of knowledge, to confirm the students' proposal of the research planning, to be there for the students in each and every stage, and to enable the free flow during the 'corrections of the way' that will ascertain that the student does not deviate from the main work (Branco Weiss Institute Website: Inquiry Process; Rozenfeld & Flik, 2002; Spector Levy & Shartz, 2001).

Processing of the Findings

This component serves to organize (classification, categorization, and ordering) the different findings, to delineate a general picture of the findings regarding the research question, to link between the inquiry question and the conclusions, and to enable a clear presentation of the findings also for somebody who is not involved in the research itself (Branco Weiss Institute Website: Inquiry Process). The processing of the findings of the scientific inquiry are a qualitative and/or quantitative description of observations or results of experiments and their analysis (Ben David, 2012). There are many forms for the presentation of the data: table, graph, figure, text. The presentation of the data needs to be clear, consistent, and transparent, so that if the research type enables it, it will be possible for another researcher to repeat this stage of the research (Pedagogical Secretary, 2008).

If we do not perform this component, then we can ‘lose our way’ among all the findings and data. We would not see a clear picture of the situation, and we might provide incorrect weight to some of the findings or to all of them. Hence, this component is very important, and the continuation without it is problematic and even impossible, if we want to establish the continuation on generalization and in a clear manner ((Branco Weiss Institute Website: Inquiry Process).

The tasks of the teacher-mentor in this stage are to instill concepts such as facts, data, and findings, to inculcate methods or skills for the processing of information required in this stage (such as statistics, information representation, comparison, etc.), to help in the classification and organization of findings (if there is the need to help in this), to teach ways to examine the reliability of the findings and to process them, to clarify whether the student addressed all the findings, and to exert judgment along with the student in the choice of the form of processing that is suited to the research type and that facilitates the drawing of conclusions (Branco Weiss Institute Website: Inquiry Process; Rozenfeld & Flik, 2002; Spector Levy & Shartz, 2001).

Drawing Conclusions

Drawing conclusions is the confirmation or refutation of the inquiry hypotheses, the scientific explanation of the experiment’s results, and the presentation of an answer about the research question. At this stage, there is the ability to discuss the experiment’s findings, to provide an established scientific explanation, to form learning or new insights regarding the research question, to create generalizations (induction), to implement principles, and to present the inquiry implications (Ben David, 2012).

In this stage, the main goal is to examine what it is possible to conclude from the findings regarding the research question and what it is not possible to conclude (Ben David, 2012; Krajcik et al., 2000; Kuhn et al., 1995). The important key word in this context is the ‘validity of the conclusions’. In other words, the degree to which the conclusions derive from the data collected and analyzed with reference to the research question (Pedagogical Secretary, 2008). Sometimes students draw conclusions without having sufficient findings to base upon or generalize their conclusion on cases that have not yet been investigated (Kuhn et al., 1995). This is also the place to discuss the research limitations, which can

derive from different factors and can influence the findings. We cannot necessarily commit to the correctness of the conclusions, since the research is performed under certain conditions, at a certain standard, and under certain limitations. The findings achieved under these conditions and the conclusions must address only the research performed under these conditions (Pedagogical Secretary, 2008).

While the report on the inquiry results must be performed with precision, with objectivity, and without personal interpretation by the researcher (to the extent possible), in the stage of the drawing of conclusions, the researcher must provide a scientific explanation (in his opinion) of the inquiry results. In other words, the researcher's personal interpretation is essential in this stage (Ben David, 2012). However, the researcher's personal interpretation of the results needs to be exercised with great caution in the reference to the results as empirical evidence disconnected from his previous beliefs and theories. Researchers indicate that this point constitutes a cognitive failure in students, who tend to adhere to the previous theories that they brought with them to the learning process, despite empirical evidence (inquiry results) that contradict their previous beliefs (Kuhn et al., 1995).

Another widespread problem in the drawing of conclusions is that students do not say the meaning of the findings in connection to the research question but tell again about the findings. It is important to note the considerable importance of the ability to differentiate between the inquiry results and the inquiry conclusions (Ben David, 2012). According to McDermott, Shaffer, and Constantinou (2000), the teachers need to be capable of differentiating between findings and conclusions and to teach the students to perform the thinking required so as to advance from findings to logical and valid conclusions.

In many cases the drawing of conclusions sparks additional inquiry questions and leads to the phrasing of new hypotheses and perhaps to stimulus for further inquiry. This is the place to propose what can be done in a continuation research study, in light of the knowledge and understanding that were achieved during the research (Ben David, 2012; Windschitl et al., 2008). The inquiry process is not complete if conclusions were not drawn from the investigation itself and an answer to the research question is not obtained. Reaching new insights is significant and makes the inquiry into an opportunity for new learning (Ben David, 2012; Branco Weiss Institute Website: Inquiry Process).

The tasks of the teacher-mentor in this component are to instill concepts such as argument, generalization, conclusion, to invite experiences in drawing conclusion in a variety of topics/events, to focus the distinction between results and conclusions, to alleviate the fear that may arise when reaching this stage, to guide the students to reach a fit between the conclusions and the data collected in the inquiry, to hold a discussion with the students on the conclusions and their meaning, and to raise questions and ideas for the continuation (Ben David, 2012; Branco Weiss Institute Website: Inquiry Process; Rozenfeld & Flik, 2002; Spector Levy & Shartz, 2001).

Presentation of the Inquiry Process and Its Products

The product of inquiry is a product that presents the researcher's conclusion or insight in a creative way and through diverse ways of expression. This stage obligates the intelligent and planned use of diverse ways for the representation and dissemination of information, with adjustment of the information type for the form of the representation suited to it (Ben David, 2012). The final product can be a visual creation (model, poster, sticker, presentation, and so on), written product (written work, diary, letters, newspaper, etc.), or verbal product (speech, public trial, presentation, social activity, radio broadcast, etc.) (Ben David, 2012; Thomas, 2000). The students present their product in front of an audience (presentation), explain it, defend it, and perform reflection on the entire learning process (Rahm, 2012).

However, we emphasize that the product is of considerable importance, but the main thing is the learning process in the preparation of the product. In inquiry based learning, the process is knowledge and a goal in its own right and not only a means for the achievement of some final product (Rahm, 2012). According to Papert (1993), the process of the preparation of the product is a process that makes learning meaningful, when the learners are involved in the experiential building of products that have personal meaning for them.

The presentation of the process of inquiry provides us with a possibility of sharing our deeds with others, provides us with satisfaction with our activity, invites constructive criticism of the inquiry results, and the process, thus promoting us and the research. This component invites a presentation of achievements and stimulus for the continuation of

investigation and responsibility for our act of inquiry (Branco Weiss Institute Website: Inquiry Process). The new knowledge that is created constitutes a basis for the continuation of the inquiry process and the construction of additional knowledge. Hence, the importance of the presentation and the wide dissemination of the inquiry process is derived (Ben David, 2012).

The tasks of the teacher-mentor are to bring to the students a variety of possible ways of presentation, to instill skills of presentation and of preparation for presentation (such as to stand in front of an audience, to be prepared to answer questions from the audience), to help choose the presentation method suited to the topic and to the student, to give the possibility and to dedicate time for peer assessment, to define criteria for the presentation and evaluation of the research process, and to provide feedback on the student's work in a structured and guided method, which does not threaten and does not upset (Ben David, 2012; Branco Weiss Institute Website: Inquiry Process; Rozenfeld & Flik, 2002; Spector Levy & Shartz, 2001)..

Evaluation of Inquiry and Reflection

The teaching and learning in the inquiry method need to include diverse tools of assessment suited to knowledge, skills, and practices to which the learners were exposed during their work (Harlen, 2003; Pedagogical Secretary, 2008; Sadler, 1989). The approach to assessment that should be adopted in learning through inquiry is the approach that combines formative assessment (also called assessment for learning) and summative assessment (Tamir, 2007). The main goals of formative assessment are to identify specific scholastic needs so as to address them in the continuation of the teaching/learning, to assess the gap between the existing situation and the desired situation, and to adopt suitable steps for the reduction of the gap and the evaluation of effectiveness. Therefore, formative assessment is assessment incorporated in learning. In contrast, the main goal of summative assessment is to obtain a general assessment on the level of the student's achievements at the end of the learning process (Birenboim, 1997, 2009; Sadler, 1989). This assessment, which focuses on grades and responsibility, has to be respected in many contexts but does not appropriately serve the student's immediate learning needs (Baron, 1990).

The assessment of the inquiry work in all its stages, by its very nature, cannot be satisfied with the measurement of the final products and cannot be performed in a one-time way at the end of the learning process. The assessment of the inquiry work needs to be performed throughout the entire work process and to follow up after the scholastic process that the student experienced (Harlen, 2003). The assessment of the inquiry does not address only the research work products but also the learning processes that the students experienced during the performance of their inquiry. These are expressed in the display of abilities and competencies acquired/strengthened during the inquiry, in the active understanding of the scientific knowledge and its connection to the problem, by the insightful achievement of the inquiry process and result. It must be composed of formative assessment, which will contribute to the development and improvement of the work, and summative assessment of the final work. The inquiry assessment needs to be performed both during the performance of the inquiry and at its end (Birenboim, 1997; Harlen, 2003). In addition, the evaluation of the inquiry should be performed by the students themselves (self-assessment), by other students (peer assessment), and by the teachers.

Self-Assessment

Learning in the inquiry approach, by its very nature, invites the student's direct involvement in the learning process. In learning of this type, the students develop skills of self-learning. They lead the process of learning, they are responsible for its progress, and they are also involved in the assessment processes (Hativa, 2003; Zohar, 2007). Thus, in each stage of the stages of the inquiry process, the student needs to examine himself and examine his progress in the different work stages (Harlen, 2003). The students will be asked to write a reflection on the entire work process and to evaluate their performances on the level of the process and the product (Loh et al., 1997; Pedagogical Secretary, 2008). As a part of the inquiry process, the student is required to perform a reflection in a number of categories: reflection on the goals of the inquiry process in the context of what is performed in the inquiry, reflection on the process (design, performance, processing, and representation), reflection on the strategies that are used, reflection of collaboration and teamwork, reflection on successes, difficulties, and ways of coping, and reflection on the inquiry process for the structuring of scientific knowledge (principles, phenomena, processes), and product evaluation (Flavell, 1979; Loh et al., 1997)

Self-assessment is a nice way to present the idea of meta-cognition to the students. Meta-cognition or ‘thinking about thinking’ addresses the person’s knowledge about his thinking and regulation and control of thinking processes. During the thinking the learners are required to plan the thinking process, to follow up and supervise the process, and to evaluate its results and products (Flavell, 1979). There is broad agreement among researchers about the importance of meta-cognition as an explicit goal for the promotion of high order thinking skills and the promotion of learning processes (Flavell, 1976; Zohar & Ben David, 2008). Especially in the present era, in the last decade of the 20th century, use is made of hybrid/blended learning, (which is learning that combines online learning and face-to-face learning in the classroom) in which the students are required to acquire knowledge independently, to provide active feedback in all the stages of the learning (and not only spontaneous participation in the lesson) and to implement reflective considerations on their work. Learning in this way, which includes self-assessment, increases the learners’ active involvement in the learning process and promotes the learners’ independence (Aleksanyan, 2020).

Peer Assessment

In addition to self-assessment, which is performed by the students themselves, peer assessment should be performed by other students. Peer assessment can be performed at all stages of the inquiry work and at its end (Pedagogical Secretary, 2008). The goal of formative peer assessment is to ask critical questions, to provide feedback to peers, to identify mistakes, and to offer suggestions for improvement (Biton, 2011).

As a result of peer assessment by students, many teachers are concerned about possible bias. The students may give higher grades than the teachers do (Sadler & Good, 2006). Therefore, it is necessary to require from the students to explain their actions in their assessment and thus to reduce the bias on a social or personal background. To avoid this bias, the students should be prepared for this type of assessment and should discuss its goals and the challenges it presents (Pedagogical Secretary, 2008). Another means for the reduction of bias is the use of a predetermined rubric, which was presented to the students and explained in detail (Birenboim, 1997). A rubric for assessment can include criteria according to which the performance will be evaluated as well as descriptions of performances at different levels of quality (Birenboim, 1997, 2009). Sometimes the teacher will provide criteria, and sometimes she will involve the students in the definition of the criteria (Perkins, 1995).

Teacher Assessment

Teachers need to assess both the learners' work process and their final products. The feedback is the core of summative assessment, and therefore it is necessary to ensure significant feedback for the student that will reflect not only the student's expertise but also the learning process (Baron, 1990; Birenboim, 2009). The teachers should provide feedback throughout a number of stages of the work and detail how, in their opinion, the student can advance and improve (Krajcik et al., 2001) and allow the student to deploy strategies for correction as necessary (Birenboim, 2009). According to Harlen (2003), effective assessment provides information about the student's learning and helps inform about the coming stages in the learning.

When feedback is provided, it is important to be aware of the students' outlook: their belief in their ability to succeed and their motivation to continue in the learning. Research studies indicate that providing effective feedback significantly improves the students' learning and increases their motivation for the continuation of the learning (Cauley & McMillan, 2010; Black & William, 1998; Sadler, 1989). Significant feedback for the student is feedback that involves the student in the making of the decision about the next step in his learning process, so that he will not be passive in the receipt of the teacher's judgment of his work (Harlen, 2003; Stiggins, 2005).

To conclude, it is necessary to provide diverse and ongoing assessment throughout the entire process of learning, from its beginning to its end. Sometimes the assessment will entail the feedback of the teachers for the students, sometimes the feedback of the students for their peers, and sometimes self-assessment and reflective thinking (Baron, 1990; Perkins, 1995).

It is important to allow the students to experience the performance of an entire process of scientific inquiry, from the phenomenon or the problem, through the conclusions and the discussion of them as well as the new questions for further research, to the process of assessment and reflection (Rozenfeld & Flik, 2002). Partial teaching of the inquiry components does not allow the student to acquire an overall picture of the ideas at the basis of the inquiry. Thus the student's ability to understand inquiry and its outcomes properly is harmed (Roberts, 2001).

In light of the actions required of the student in the inquiry process, which were mentioned in the previous sections, and in light of the tasks of the teacher detailed above in each component of the inquiry, it can be seen that the learning through inquiry obligates a change in the perception of the role of the student in the class and that teaching through inquiry is a way of teaching in which the teacher has an important role but it is different from her traditional place (Kapach, 2014; Zohar, 2007).

1.1.3 Change of the Perception of the Role of the Student and the Role of the Teacher in the Performance of the Inquiry Process

The main point of the teaching is not what the teacher does but what she causes students to do (Perkins, 1995). The learning through inquiry removes the student from the passive position of the listener and uses the student in an active process of the creation of new knowledge (Goodnough, 2006; Zohar, 2007). The student shifts from the repeater of information who is subordinate to the teacher's authority to the developer of knowledge, who initiates and thinks critically (Anderson, 2002). Learning through inquiry is active learning, in which the student builds his personal knowledge, during the learning, through experience. In this method, the student searches for an answer to the question and in the framework of the search he must implement independent thinking (Zohar, 2007).

To integrate the inquiry approach, teachers must integrate new practices in the traditional teaching. In particular, they must shift from management, according to which they dictate to their students what to research and how to perform the investigation, to a situation in which they listen and guide their students how to decide what to investigate and how to shape the research for themselves (Kapach, 2014).

Therefore, it is necessary to adopt into the educational system new styles of teaching. Primarily teaching that emphasizes thinking tools as opposed to repetition, ability to work in a team as opposed to individualized homework, personal pace of learning, differing from one individual to the next, as opposed to uniform learning in the group, multidisciplinary learning as opposed to the inculcation of knowledge in specific fields, ability of generalization and integration of material as opposed to focus on a specific problem, and ability to search for information on the Internet and on the information networks and to catalogue it as opposed to storing it in the memory, ability to differentiates

what is important from what is trivial (Albert, 2000; Birenboim, 1997; Gibson & Chase, 2002; Pedagogical Secretary, 2015). This change is a real revolution in the teacher's role, and therefore an essential condition for the assimilation of learning through inquiry in the educational system is the long-term professional development and support of the teachers in the classes (Kapach, 2014; Pedagogical Administration, 2015).

A teacher who was trained to be a teacher for teaching by inquiry needs to have knowledge and abilities for guidance suited to teach in the inquiry approach (Kapach, 2014). First, the teacher must surrender her role as a repeated of information and instead fill a role of inspiring curiosity and providing challenges, which will motivate her students to ask questions that interest them (authentic issues). The teacher needs to be attentive to her students and to behave flexibly following her students' interest, curiosity, and needs (Harpaz, 2000). The teacher needs to be involved in the complex processes the students experience and help them navigate on their way from the moment the problem arose until an adequate and established solution is found (Chinn & Malhotra, 2002). The teacher needs to aspire to reduce the student's dependence on readymade answers. The teacher needs, from time to time, to free her students from the need to absorb and assimilate arranged theories and to allow them personal space to move freely in the sea of information. The teacher should let the students think for themselves, to ask questions, to investigate, to evaluate what they know, to consider and to make decisions, to reach conclusions, and to form a way to present her new knowledge in a convincing manner. The students are responsible for their learning (Anderson, 2002; Goodnough, 2006; Zohar, 2007). Simultaneously the teacher is always found in the background, to channel and direct the student towards the goal, and preserves the level of challenge and reward of the motivation at all times (Chinn & Chia, 2004).

The additional knowledge and abilities required of the expert teacher in the field of inquiry are:

- To understand not only what is known in science but also the evidence and lines of thinking that will lead to this knowledge. In other words, to understand the variety of skills and processes that are involved in inquiry and how they develop during the learning (McDermott, Shaffer, & Constantinou, 2000; Watson & Manning, 2008). It is very desired that the teacher has personal experience in inquiry (Dreyfus,

- 2006). The teacher will know the students' perceptions and difficulties in the topic of scientific inquiry and will be able to propose ways of coping (Rozenfeld & Flik, 2002).
- To inculcate and to develop skills of inquiry in each one of the components of inquiry (as detailed in the previous sections). These skills do not develop spontaneously among most students. They need to be learned explicitly and in well planned manner (Castello & Monereo, 1999; Plucker & Nowak, 1999; Zohar & Nemet, 2002).
 - To adjust inquiry activities to the students' abilities and needs and to determine the level of inquiry suited to them (Hofstein et al., 2004; Taitelbaum et al., 2008). The teacher should examine the knowledge required of the students in every stage of work and decide, in light of the requirements and in light of their age, experience, and the learning goals, on the concepts and skills to inculcate in them and the degree of support and accompaniment for the students (Branco Weiss Institute Website: Inquiry Process).
 - To encourage the students to cooperate and share knowledge with their peers, in the way of a supportive learning environment, in which the learning occurs as a collaborative process of the students and the teachers (Hofstein et al., 2004; Taitelbaum et al., 2008). It is recommended to conduct learning through inquiry through collaborative learning: the students work in groups and hold discussions and conversations, while the teacher moves from group to group and instructs. The teacher-mentor is a partner in the dialogue and ideas of the students and enriches the collective thinking (Vygotsky, 1978; Watson & Manning, 2008). However, collaboration in inquiry learning will not bear fruit without the teacher-mentors awareness of them and without planning of explicit teaching aimed at achieving them (Ben David, 2012).
 - To hold a discussion with the students about the criteria for the assessment of their learning, the skills, and the processes, to help them choose the correct instruments for progress and development, and to help students identify in themselves the next step required for the achievement of their goals in the context of a certain investigation (Watson & Manning, 2008). A meta-cognitive discussion must

accompany all the stages of the process of the structuring and implementation of the inquiry skills. It is very important that in every stage the teacher integrate questions in the meta-cognitive aspect (Zohar & Ben David, 2008).

- To evaluate the students' performances in methods of ongoing alternative assessment in the learning process (Hofstein et al., 2004; Taitelbaum et al., 2008). This assessment obligates a change of the teaching and learning method, since it does not occur at the end of the learning but during it. It assesses progress, reflective and critical ability, and meta-cognitive thinking, as well as the student's cognitive abilities (Birenboim, 1997; Zohar & Ben David, 2008).
- To plan together with the students their schedule for the inquiry work, from the stage of asking question to the stage of assessment (Rozenfeld & Flik, 2002; Spector Levy & Shartz, 2001).

To conclude, as we have seen above and in the previous chapter, the tasks of the teacher who instructs students in an inquiry process are diverse and composed of different types of interactions with the students and with the different materials. In light of the teacher's many tasks and in light of the fact that today the world is flooded with considerable knowledge, the teacher cannot teach everything and the student cannot learn everything. Therefore, it is necessary to change the perception of the role of the teacher and of the traditional teacher (Benjamin, 1989; Kirschenbaum & Simon, 1974; Salomon, 2000). The main change of the perception of the student's role in learning through inquiry is the transition from a student who is a 'passive absorber' of knowledge to a learner who is involved and active in the learning process, a learner who is responsible for and controls the learning process. Transition from a student is subordinate to the teacher's authority to a student is developer of knowledge and thinking critically (Anderson, 2002; Hativa, 2003; Pedagogical Secretary, 2015; Zohar, 2007). The main change of the teacher's role from a traditional teacher to a teacher who leads inquiry is the transition from a teacher who gives instructions to the student to a teacher-mentor who supports and accompanies the students (Bartels, 1998; Bybee, 1997; DeBoer, 2000; Kapach, 2014; Linn, 1992; Sage & Torp, 1997; Zohar, 2007).

The teacher is supposed to instruct the student to find the solution to the researched problems, when the degree of instruction of the teacher changes from time to time, ranging from full instruction of the teacher at one end to the non-instruction of the teacher at the other end, when in the middle there is a middle situation in which the teacher helps the student research by himself (Dreyfus, 1995). Do all the processes of inquiry require from the learner the same level of inquiry? The answer is no (Schwab, 1962; Herron, 1971; Martin-Hansen, 2002; Ben David, 2012). The next chapter describes various levels of inquiry, which differ in the degree of the student's independence in the research work and in the degree of the teacher's involvement.

1.1.4 Levels of Inquiry in the Inquiry Process

Schwab (1962) divided the teaching of the inquiry into three levels. The levels were determined according to the degree of the student's involvement in the inquiry process, the extent to which the teacher instructs the student during the inquiry, and the background the student has regarding the researched problem. The basic level is that the student is presented with the research question and the work methods that lead to the solution and the solution to the question is not given. On the second level, the research question is presented to the student but the student must decide on the work methods and must provide the solution. On the third level, all the research stages remain 'open' to the student. On this level the student's degree of independence is the highest, the student needs to formulate inquiry questions, to decide on the work methods, and the solutions remain open.

In a similar way, Tamir (1971) and Herron (1971) divide the teaching of inquiry to three levels, which are presented in the following table. The first level is guided discovery (three different possibilities, see the table). The second level is pure discovery, in which the student is presented only with the problem and is not presented with rules, examples, and solutions. The third level is the inquiry method, in which the learner himself needs to define the problem.

Table 1: Different Levels of Inquiry Teaching, (+) Indicates Directions Given to the Student by the Teacher (Tamir, 1971)

Way of Teaching	Problem	Rules	Examples	Solutions
Exposition	+	+	+	+
Guided Discovery	+	+	+	-
Guided Discovery	+	+	-	-
Guided Discovery	+	-	+	-
Pure Discovery	+	-	-	-
Inquiry	-	-	-	-

Inquiry according to this table is characterized by a minimum of guidance and direction of the teacher and the maximum of openness and flexibility. Herron (1971) added another level, as a basis of three levels. On this level, the student receives the inquiry question, the solution to the problem, and therefore expository learning occurs, since the student was given all the contents in their final form and this stage in essence is the ‘confirmatory’ stage.

This division was used as the basis of the division of the inquiry into the four levels accepted today (Martin-Hansen, 2002; National Research Council, 2000), when the differences between the levels are related to the student’s degree of independence and the teacher’s degree of involvement when the inquiry is performed.

Structured inquiry is inquiry that for the most part is performed through full instruction of the teacher in all the stages of the research. The student works according to the teacher’s directives, which lead to the pre-known discovery. In this case, the student’s involvement in the task is limited to the performance of the teacher’s instructions. Therefore, the argument is that in activity of this type there is no true investigation. However, it is possible to integrate in the activity tasks that can involve the student in the performance of activity such as the students will make a hypothesis, will build by themselves the table of the collection of the findings, will explain how the performance of the experiment strengthens what is researched (Martin-Hansen, 2002).

Ben David (2012) describes that on the level of structured inquiry the students receive most of the components of the inquiry pattern: formulation of the problem/goal of the inquiry, the inquiry question (including the definition of the dependent variable, independent variable, and relation between them), inquiry hypothesis, instructions for planning and performance of the inquiry, patterns prepared for the collection of the data (measurement tools, measurement units, tables suited for the data, instructions for the presentation of the data in suitable figures), milestones for the confirmation or refutation of the hypothesis, for the drawing of conclusions, and for the formulation of the answer to the inquiry question. The students perform the experiment/observation and are required to present the inquiry process and its conclusions independently. Some compare this level of inquiry to the work according to a 'recipe book' until the desired outcome is obtained. This process is called in the teaching sciences the 'confirmatory laboratory' (Domin, 1999).

Guided inquiry is when the teacher helps the student in the inquiry process. Generally the teacher chooses the inquiry questions, and the teacher and the student decide together how to continue in the investigation of the problem. The teacher is involved and gives work directions in all parts of the inquiry work, with the exception of the stage of the drawing of conclusions which the students need to perform by themselves (Martin-Hansen, 2002). Here too the students perform the experiment/observation and are required to present the inquiry process and its conclusions independently (Ben David, 2012).

Open inquiry is a process in which the student is at the center. He asks the inquiry question and he decides on the ways of inquiry, until the end of the process. In this style the student (and not the teacher) is required to formulate the problem, to declare the investigation goal, and to perform the investigation independently (to plan and to perform in actuality experimentation and to formulate relations between the findings). The very raising of the research question independently is the key to open inquiry. This is the highest level of inquiry achieved, when the students have the utmost independence in all the inquiry stages. Therefore, this is the approach that reflects to the greatest possible extent the scientist's work. In essence, here the student experiences real inquiry work (Domin, 1999; Martin-Hansen, 2002).

Ben David (2012) calls this level independent inquiry, in which the students do not receive the inquiry pattern but perform all the inquiry stages independently. The students are free to focus on the topic/phenomenon according to their desire. Following the review of a scientific background on the topic or following an initial observation of the phenomenon, they formulate questions they are curious about and perform all the stages of inquiry independently, including the stage of the presentation of the inquiry process and its conclusions. In addition, open inquiry obligates a close relationship between the teacher-mentor and the student, even at times that are not in the schedule. The teacher must encourage the student to take responsibility for his learning and to give his student moral, social, and cognitive support (Chinn & Chia, 2004). Domin (1999) emphasizes that in this style the outcomes of the inquiry are not known ahead of time to the student and are not necessarily known to the teacher, to differentiate from guided inquiry, in which the teacher guides the student to a discovery that the teacher knows.

The open inquiry approach according to Hodson (1990) enables the student great independence in the management of the research. The student identifies the problem and reaches the conclusion on his own. Hodson notes that it is necessary to attribute to this approach great importance in scientific education, since during open inquiry the student draws closer to the doing of 'real' science. Chinn and Malhotra (2002) emphasize that on the scale that examines the relationship between laboratory activity in the classroom and the authenticity of the laboratory in science, inquiry activity is the closest to scientific inquiry. The highest level of inquiry will be achieved as the student will be more independent and will perform activities similar to those undertaken in the performance of the research by scientists (Herron, 1971; Schwab, 1962).

Coupled inquiry combines guided inquiry with open inquiry and constitutes an intermediate level between these two levels of inquiry. The student first performs guided inquiry and then he performs open inquiry. The teacher lets the student choose the inquiry question from a set of predetermined questions (Martin-Hansen, 2002). The students will perform independently the stage of the planning and performance of the inquiry and not only the stage of the conclusions and their presentation, as in guided inquiry (Ben David, 2012).

From the aforementioned statements, it can be seen that the inquiry process entirely entails complex and long term teaching/learning and constitutes a rather significant cognitive load on the teacher and on the students. Ben David (2012) proposes that one of the ways to relieve load entailed in the inquiry process is to avoid the scientific inquiry process as a constellation and to adopt the teaching model that she calls the ‘zipper model’. This teaching model proposes to move gradually on the scale between structured inquiry and open inquiry. In other words, to begin with the ‘closed zipper’, the structured inquiry task, in which the students receive the inquiry task ‘ready-made’ and are required to implement it and to present it. Gradually ‘open the zipper’, each time with the requirement of a new inquiry skill, until the open inquiry task, in which the students implement all the inquiry skills themselves.

Kapach (2014) also recommends incorporating the inquiry in the laboratory through activities in the steadily advancing levels of inquiry, from ‘closed’ laboratory activity through ‘semi-closed’ activity to open activity. In the research literature, there are additional recommendations according to which it is necessary to combine inquiry at a variety of levels, when together they build the process of learning through inquiry (Martin-Hansen, 2002; Schwab, 1962).

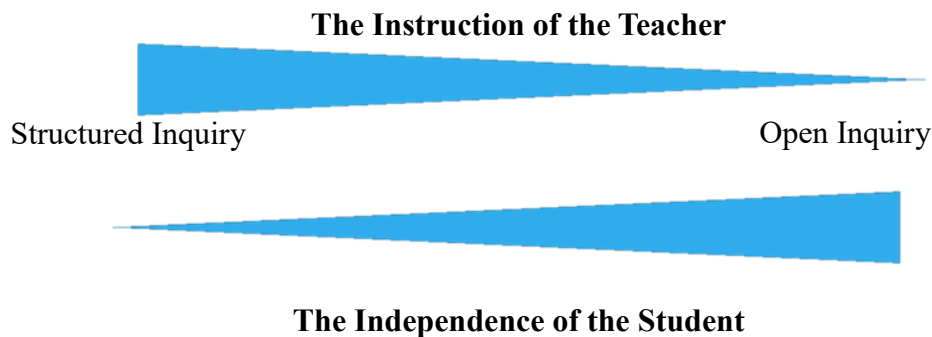


Figure 2: Recommendations to Combine Inquiry at a Variety of Levels, to Move Gradually on This Scale between Structured Inquiry and Open Inquiry (Sigron, M)

In the level of structured inquiry, usually the same task for all students, the student works according to the teacher’s instructions, which lead to the pre-known discovery. Then the degree of instruction of the teacher decreases and the degree of independence of the student increases. The open inquiry is the highest level of inquiry, task, selected according to a student’s personal interest and abilities, and the student achieves the utmost independence with the minimum instruction (Ben-David, 2012; Kapach, 2014; Martin-Hansen, 2002; Schwab, 1962).

Using inquiry, in all its levels, the students discover new things and add knowledge to the field of knowledge the inquiry addresses (Hodson, 1990). The following question is therefore asked. Why do we need to ‘play’ with the levels of inquiry? And the answer is that every level has advantages and disadvantages (Zohar, 2007).

1.1.4.1 Advantages and Disadvantages in Teaching Inquiry in the Class in Its Different Levels

In this chapter, we will present the opinion of critics and proponents of four styles of inquiry mentioned in the previous chapter: structured inquiry, guided inquiry, open inquiry, and coupled inquiry. There is no consensus regarding the preferred inquiry method for teaching in the class. It is possible to find in the research literature differences of opinion regarding the manner of teaching of inquiry in the class and especially the effectiveness of the open inquiry teaching for high school students (Domin, 1999; Martin-Hansen, 2002; Trautmann et al., 2002; Windschitl, 2003; Hofstein & Lunetta, 2004; Trautmann & MaKinster, 2005; Brown et al., 2006;; Zohar, 2007).

The critics of the structured level of inquiry (“the confirmatory laboratory”) maintain that there is little thinking in it and that it is not effective for perceptual change and is not suited to the way in which scientists work (Domin, 1999). Zohar (2007) maintains that at this level (the students are given the problem, the planning of the way of the solution, and sometimes even the conclusions ahead of time) the students generally pass through all the stages of the inquiry but in essence all the stages are closed and given to them beforehand. The students are perhaps active with their hands but in their thoughts they have very little to do themselves. It is not that this has no value, but the level of inquiry is very low, in essence non-existent. When the laboratory briefing dictates to the students what to think, how to think, and when to think, the laboratory activity in the end loses its ability to influence the learning and loses its authenticity in the reflection of the work of science (Girault, d’Ham, Ney, Sanchez, & Wajeman, 2012; Pushkin, 1997). Therefore, it is not enough to show the learner how to learn what is already known; rather, it is necessary to teach him how it is possible to discover what is not yet known (Etkina et al., 2002).

Sometimes guided inquiry is more effective, especially when there is a need for in-depth understanding and the development of logical contexts. The proponents of guided inquiry maintain that it is more practical; since the student is directed to the desired goal, precious time is saved. The engagement in guided inquiry requires less time than most of the activities in the framework of open inquiry (Furtak, 2006; Staer, Goodrum, & Hackling, 1998). In addition to the advantage expressed in the savings of time, there is another advantage expressed in the student's frustration, which may be caused following the attainment of unexpected outcomes or failure when engaging in open inquiry (Zohar, 2007). However, in guided inquiry a situation may be created in which the emphasis is on the practical performance of any experiment, and the main activity of the student becomes technical, without the understanding of basic inquiry skills related to planning (Ogens, 1991). Therefore, it is necessary to enable the students, according to Chinn and Malhotra (2002), to be more independent and to challenge them more in the direction of open inquiry.

The proponents of inquiry on its high levels, primarily open inquiry, maintain that they involve the students not only in the learning of the concepts themselves but also in the learning of the scientific process and its methods. On the high levels of inquiry, the student is obligated to think critically about the way in which he understands the concepts and about the process he performs (Domin, 1999). In activities of the 'open laboratory', the student is greatly involved in solving the problem and is committed to thinking and discussing all the stages of the inquiry. As a result, these activities provide good opportunities for the development of creative thinking and the development of high inquiry skills (Hofstein & Lunetta, 1982; Sandoval & Reiser, 1997). In open inquiry experiments, every one of the students in the group has higher personal responsibility for the planning and performance of the experiment than in guided inquiry and the experiments necessitate higher thinking skills regarding the planning and criticism relative to the performance ways (Martin-Hansen, 2002). Students who engaged in open inquiry and conducted independent inquiry were exposed to and reached areas that were beyond the accepted areas of science learned in the class and acquired more considerable knowledge related to the problem they addressed (Chia & Chin, 2006).

In addition, the students' experience in inquiry and in the explanation of results obtained following the performance of the inquiry strengthens the student's feeling of belonging for activity and products, thus enabling the students to feel a part of the scientific community, brings the learner as close as possible to the true world of the scientist and may help them understand the nature of science (Domin, 1999; Sandoval & Reiser, 1997). As the students are more independent in the inquiry they perform, they develop more positive attitudes towards science (Ornstein, 2006).

Alongside the advantages of open inquiry and the many recommendations to integrate teaching according to the inquiry method, teachers find it difficult to teach open inquiry because of different reasons. These reasons are connected to the means, to the teachers themselves, to the students, or to all three factors. It is important to address the challenges and the difficulties the teachers face when they incorporate inquiry-based teaching in their traditional teaching (Anderson, 2002; Brown et al., 2006; Domin, 1999; Zion et al., 2007).

1.1.4.2 Challenges and Difficulties Faced by the Teachers and Students in the Open Inquiry Process

Challenges and Difficulties regarding the Means (Time, Number of Students in the Class, and Equipment)

In contrast to the proponents of the advantages of the open inquiry process in the teaching of the sciences, some maintain that open inquiry is difficult to perform. The critics of open inquiry hold that the scope of the work and the framework of time required for their performance are more demanding than structured research, both for the learner and for the teacher (Domin, 1999). Teachers hold that the given time framework is too short to encourage the student to be independent, to acquire inquiry skills, to plan a project, to perform it, and to summarize the findings in writing (Zion et al., 2007).

In addition, teachers maintain that the integration of inquiry, and especially open inquiry, delays the completion of the teaching of the contents of the curricula. According to the teachers, the curriculum is very busy and the preparation for the final tests in the high schools is very important in their opinion, thus preventing the use of different teaching

methods and ‘deviations’ from the curriculum, and therefore the time allocated for the inquiry activities is most limited (Brown et al., 2006; Zion et al., 2007). In contrast, Henson (1986) presents research studies that show that teaching through open inquiry constitutes compensation for the slow progress in the teaching of the contents.

The engagement in open inquiry, according to the teachers, takes a lot of time and necessitates considerable investment and effort in the planning of the lesson and can also go beyond the time of the lesson and beyond the learning hours in the school (Costenson & Lawson, 1986). In addition, the inquiry process that is intended to involve the students’ thinking creates a cognitive load that requires the considerable investment of time and effort from both the teacher and the students (Ben David, 2012). However, Ben David (2012) holds that the benefit that can be derived from the scientific inquiry process can justify the effort invested in it.

In addition to the problem of time, the class size also has impact on the effectiveness of the learning in the class. In large classes, the teachers prefer to adhere to guided inquiry and structured inquiry (also called confirmatory laboratory) since these styles can be performed with a large number of students and in a relatively short framework of time (two to three lessons) (Domin, 1999). Teachers maintain that it is hard to perform in actuality a full or open inquiry in a large class since the activities are not necessarily based on work sheets and are not identical for all but are open to the student’s self-learning and different from group to group, even when every class performs the activity around this phenomenon (Anderson, 2002; Brown et al., 2006).

Additional problems that prevent teachers from engaging in open inquiry are related to the technical side: the need for diverse equipment that is not entirely found in a school laboratory, the non-availability of equipment, and the need to use the laboratory assistant differently (Staer et al., 1998; Welch et al., 1981). Dreyfus (2006) strengthens the argument that the inquiry approach, on its higher levels, is a more demanding approach in terms of the resources and that the teacher may encounter difficulties entailed by the absence of equipment, materials, and unavailable laboratory rooms.

Challenges and Difficulties regarding the Teachers

Beyond the challenges presented above, such as the lack of time, lack of equipment and materials, performance of inquiry in a large class, and the need to prepare the students for the final examinations in the high school, the integration of inquiry based teaching places more than a few additional challenges in front of the teachers. These challenges are related to the teachers' expertise in the inquiry based teaching, their perceptions regarding science in general and inquiry in particular, and there is fear of change of teacher's role, from a traditional teacher to a teacher who leads inquiry (Brown et al., 2006; Bybee, 2000; Hofstein & Lunetta, 2004; Krajcik et al., 2001; Langley & Alon, 2007; Rutherford, 1964; Trautmann et al., 2002; Trautmann & MaKinster, 2005; Wallace & Kang, 2004; Windschitl, 2003).

Since the 1960s, the attempt to teach using the open inquiry approach is steadily more apparent (Hodson, 1996). According to the NRC, the students are supposed to acquire their scientific knowledge through a process of open inquiry that includes asking authentic questions, planning and performing experiments, using appropriate ways to collect data and draw conclusions, through critical reference to the entire process (NRC, 1996, 2000). Although this definition seems sufficiently explicit, the process of inquiry is performed in classes in different approaches, according to the teachers' interpretation and pedagogical knowledge (Keys & Bryan, 2001). The main factor that influences the teacher's intention and ability to teach science as inquiry is the teacher's personal outlook about the pedagogical aspects of the inquiry process (Crawford, 2007). Teachers who prefer to control what is done in the class, the structuring of the knowledge, and the drawing of conclusions by the student will find it difficult to integrate in the class open inquiry (Bencze, Bowen, & Alsop, 2006). This is especially prominent among teachers who do not have experience in the management of authentic inquiry, who generally lack understanding about the inquiry process (Trautmann & MaKinster, 2005; Windschitl, 2003).

It is clear, therefore, that the teacher has decisive impact on the inculcation of inquiry skills for students and not all the teachers were trained or are trained for this (Lidar, Lundqvist, & Östman, 2006; Welch et al., 1981). Research studies note that most of the teachers lack experience in scientific research, and it is doubtful whether they themselves learned in the inquiry method and experienced inquiry in their learning, and they lack

knowledge and understanding about what inquiry is (Kapach, 2014; Krajcik et al., 2001; McDermott et al., 2000). The traditional courses for the training of teachers train the teachers very little, if at all, to teach in the inquiry-based approach, and therefore it is not surprising that the teachers are afraid to integrate open inquiry in teaching and find it difficult to provide help for students in the asking of meaningful questions, the planning of the experiment, and the drawing of conclusions that arise from the findings they collected, and the implementation of strategies for the inculcation of work in groups (Krajcik et al., 2001; McDermott et al., 2000; Trautmann & MaKinster, 2005; Windschitl, 2003; Zohar, 2007).

Teachers think that they need to know all the answers to the students' questions, but there are questions that the teacher may not know the answer to, and therefore they avoid encouraging inquiry among the students, especially the open inquiry method (Hogan & Berkowitz, 2000; Trautmann et al., 2002).

Teachers are also afraid of coping with ambiguity, situations of uncertainty and insecurity, all of which are part of open inquiry (Shedletzky & Zion, 2005). Some are afraid that the lack of scientific knowledge will cause a change of the students' attitude towards them (Zion et al., 2007). Some teachers fear that they will not know to cope with unexpected outcomes (Tamir, 2007). Other teachers feel uncomfortable with a large number of student questions and their obligation to provide the answers, even if they know the answers to these questions (Chin & Osborne, 2008).

Therefore, it is necessary to bring the students to the awareness that the teacher cannot provide the answers to all the questions and to guide them in the accepted ways to find answers to these questions, such as planning and performance of research. According to Yip (1999), an appropriate response to such question can improve the students' understanding and encourage the motivation to learn.

In addition to all these fears, another fear is expressed by teachers with regard to open inquiry about two types of students: students with low achievements, who must be led stage after stage in this process, and students who will become frustrated or bothered when they expect clear and unequivocal answers and in the open inquiry method they will not always attain such answers (Trautmann & MaKinster, 2005). Many teachers have experienced disappointments when students failed because some of the students were not ready for the challenge and learning through inquiry was above their ability (Berg et al., 2003).

One of the research characteristics is the understanding of the place of doubt and uncertainty. Therefore, the teacher must be skilled and appropriate training is necessary (National Research Council, 2000). For this purpose, the teachers, even those with experience in teaching, need intensive and comprehensive in-service training that will equip them with the requisite knowledge and skills and the appropriate instruments for the making of a change in their practice. The in-service training will prepare the teachers to have the knowledge and abilities for instruction suited for teaching in the inquiry approach and will give them new strategies of teaching and strategies of alternative assessment unique to the inquiry approach (Kapach, 2014).

Dreyfus (2006) adds that the instruction of inquiry requires specialization that includes personal experience in the challenge of the inquiry of the unknown, peer supervision, and partnership in the inquiry in the team with students, not as a knowledgeable factor but as an adult partner. Therefore, he recommends placing the teachers in situations in which they can feel the power of the strategy entailed by inquiry, can be involved personally in the inquiry process, and can observe the students involved in the process. The teacher must have personal experience in inquiry so as to develop appropriate sensitivity to the student's experience and incentivizing partnership in the deliberations. This specialization is a change of paradigm for the teacher, from training for regular teaching, and is linked with personal experience in the exposure to non-knowledge and creative partnership with the student. This is a process of assimilation that necessitates training and mentoring (Dreyfus, 2006; Vygotsky, 1978, 2004).

Beyond the difficulties of the teachers with the integration of inquiry in the class, as detailed above, there are differences of opinion about the effectiveness of the teaching of open inquiry also with regard to the students.

Challenges and Difficulties with regard to the Students

The process of open inquiry brings the student from a passive position of absorbing, remembering, and understanding and moves the student towards an active learning process, a process in which he needs to cope by himself with questions, issues, and dilemmas, for which there are no prepared answers and sometimes there are no unequivocal answers (Zohar, 2007). The student must develop for himself a proper strategy that will lead him to

appropriate answers. He must identify by himself the information that is missing, classify it, filter it, organize it, edit it, process it, identify additional information, validate it with previous knowledge, evaluate it critically, draw conclusions, and thus continue until he finds a creative solution, established and reasoned (Martin-Hansen, 2002; NRC, 1996, 2000).

According to Sandoval (2005), many students find it difficult to conduct independent research. Sometimes students who are supposed to perform inquiry works feel confused and frustrated since the instructions for the performance of the works are not clear to them (Zohar, 2007) or since they are afraid of failure and coping with failure (Trautmann et al., 2002). In contrast, other researchers hold that this concern may serve as a lever for learning, and it was found that the failures opened a way to the acquisition of additional inquiry skills (Avery et al., 2003; Luckie et al., 2004; Ritchie & Rigano, 1996).

According to Ogens (1991), although students enjoy practical inquiry activities (such as laboratory activity), they do not necessarily internalize concepts and principles, do not necessarily acquire thinking skills, skills they expected to acquire in the framework of the performance and learning of inquiry activities. In many cases, it was found that students find it difficult to summarize the principles of the experiment that they just performed and generally cannot choose a hypothesis to explain the phenomenon or explain the stages in the planning of the experiment and understand the role of supervision, although they learned in the inquiry method (Ogens, 1991; Tamir et al., 1998). In the same trend, they found it difficult to suggest new inquiry questions based on what was learned when coping with the experiment they performed beforehand (Berg et al., 2003).

For our students to perform appropriate processes of inquiry, the teachers need to equip them with a variety of skills, to develop in them high order thinking abilities, such as critical assessment and intelligent analysis, asking and phrasing questions, searching for creative solutions and the ability to act, autonomously, to find established answers (Martin-Hansen, 2002; NRC, 1996, 2000). Along with this, it is important that teachers provide a good learning experience for students who perform the inquiry projects, so as to prevent frustration among the students (Trautmann et al., 2002; Trautmann & MaKinster, 2005).

Learning through inquiry can be combined in a variety of learning environments. The laboratory is one of the possible environments for the combination of the inquiry approach (Kapach, 2014). The research proposed here will be conducted in the framework of the integration of inquiry in the physics laboratory environment among high school students.

1.2 The Laboratory in the Teaching of Physics and the Integration of Inquiry Activities

This subchapter presents the role of the laboratory in the teaching of the sciences in general and in the teaching of physics in the high school in Israel in particular. In addition, this part describes the importance of the laboratory activity and its educational effectiveness, and concurrently questions will be raised on the effectiveness of the practical work performed in actuality today. At the end of the subchapter, different initiatives that integrate the learning of inquiry in the teaching of physics today in Israel will be presented.

1.2.1 The Role of the Laboratory in the Teaching of the Sciences

Experts in the teaching of the sciences agree that the laboratory constitutes a unique arena for the teaching of science and that the correct use of it contributes greatly to the promotion of the learning (Abrahams & Millar, 2008; Hofstein & Lunetta, 2004). The experiences in the laboratory expose the students to phenomena of nature, enable students to directly interact with the real world, and provide students with opportunities to think about real problems, while using quantitative tools, models, and scientific theories (National Research Council, 2005). According to the National Research Council (2005), the goals of the learning that can be achieved from activities undertaken in the laboratory environment are the reinforcement of the expertise in the knowledge of the scientific content, development of scientific thinking, understanding of the complexity and lack of clarity in the empirical work, development of practical skills, understanding of the nature of science, cultivation of the interest in science and in the learning of science, and development of abilities of teamwork.

The teaching in the laboratory provides a unique scholastic atmosphere. The less formal atmosphere (in comparison to the classroom) and the opportunities for greater interaction between the students and the teacher and among the students themselves have the potential to cultivate positive social interaction and thus to create a positive and constructive scholastic atmosphere towards science and cognitive development (Tobin, 1990; Hofstein, & Lunetta, 2004). There is also evidence of the fact that students find the practical work in the laboratory to be effective and enjoyable in comparison to other teaching and learning activities (Abrahams & Millar, 2008). Pushkin (1997) maintains that the laboratory is a place for social change, growth, and cognitive maturation.

According to Abrahams and Millar (2008), the effectiveness of the activity in the laboratory is measured not only by the confirmation that the student performed what the teacher asked him to perform but also by the examination of the opportunities for students to think, speak, and exchange opinions regarding what they are doing. In the same way, the effectiveness of the activity on the level of the learning is not only that the student knows to describe the tools, the actions he performed during the activity, and the characteristics of the data collected but also that the student will evince understanding about the scientific content knowledge that the activity was shaped to promote (concepts and ideas). Similarly, Gunstone and Champagne (1990) posited that effective learning in the laboratory will occur if time and opportunity are given to students for interaction and thinking so as to initiate a discussion. According to Gunstone (1991), when the laboratory is properly planned, it may fill an important role in the achievement of cognitive skills such as scientific thinking, inquiry skills, and understanding of the scientific process.

Although the laboratory has an important and central role in scientific education, more than a few experts in the teaching of the sciences raise wonderings about the effectiveness of the practical work because of the way in which it is accomplished in actuality (Abrahams & Millar, 2008). Hodson (1990) criticizes the work in the laboratory and maintains that for the most part it is not used intelligently and true activities that the students need to perform in the laboratory are not the focus. According to Gunstone (1991), the students in the laboratory generally engage in technical actions and procedures required by the experiments and are not given many opportunities to research, to think, and to present their interpretations and opinions on any activity. In the laboratory, the learners are

given very few opportunities to present questions about a given phenomenon, to conduct practical research, and to examine different ideas (Baird, 1990; Keys et al., 1999). Hence, the traditional laboratory loses the authenticity of the role of the experiment in the development of science (Etkina et al., 2002).

Therefore, educators in the teaching of the sciences in Israel and around the world (Bybee, 2000; Krajcik et al., 2000; Barrow, 2006; Zohar, 2006; Hofstein et al., 2007; Langley & Alon, 2007; Kapach, 2014) recommend combining an inquiry-based approach in the teaching of the sciences, since in inquiry learning it is possible to aspire to authenticity in the scientific work and to develop high order thinking skills and skills for independent work (in addition to the reinforcement of the disciplinary knowledge). According to Hofstein et al. (2007), the integration of inquiry in the laboratory promotes goals that are not achieved in the traditional approach. Hofstein and Lunetta (2004) maintain that in the inquiry laboratories there is potential for the promotion of the student's learning, for the greater depth of their understanding of the scientific concepts, and for the understanding of the nature of science.

The next section will describe the activity of the laboratory in the teaching of physics in the high school in Israel and the main ways of teaching in the laboratory. Then, in section 2.3, it will present different initiatives that combine inquiry in the teaching of physics in the high school in Israel.

1.2.2 The Role of the Physics Laboratory in the Upper (High) School in Israel

From the website¹ of the curriculum in physics for the upper school (high school), the Department for the Planning and Development of Curricula, the Ministry of Education, the State of Israel, the program for the studies of physics in the upper school in Israel includes theoretical studies and experiential studies in the physics laboratory in three compulsory topics: mechanics, electromagnetics, and radiation and materials. In addition, it is noted that the laboratory activity is the foundation stone in the teaching of physics and therefore the laboratory needs to be integrated regularly and fluidly into the learning and is an inseparable part of it (Department for the Planning and Development of Curricula, 2016).

¹ http://cms.education.gov.il/EducationCMS/Units/Tochniyot_Limudim/Physics/5/AlHatochnit/Ekronot.htm
(Hebrew)

The general scope of the studies in the laboratory until July 2016 is 20% of the general score of the physics studies on the higher level-5 units (It should be noted that high school matriculation examination in physics in Israel is divided into different levels: one unit of study, three units of study, and five units of study, when 5 units of study is the highest level) (Physics Supervisor Coordinator Circular, 2009). From the year 2016 the laboratory part constitutes 15% of the final score of the high school matriculation examination in physics at the five units of study level. As aforementioned, the laboratory is an integral part of the studies of physics in the high school in Israel, in other words, the laboratory hours fit into the theoretical studies of the different topics (Physics Supervisor Coordinator Circular, 2015).

There are two ways of test-taking in the framework of the high school matriculation examination in the laboratory in physics in Israel:

1. Regular Laboratory Test – Traditional Laboratory

In this framework every student will be examined on laboratory activity once from seven predetermined laboratory activities for the student. Three experiments are from mechanics, three from electromagnetics, and one is the teacher's choice from any field. From the year 2016 at least one experiment that uses computerized measurement (a sensor that connects to a computer and not simulation) will be used. From the activities it is definitely possible to integrate activity such as analysis of a video film, construction of a simulation, use of simulation or analysis of the findings of an experiment – but no more than one activity of every type (Physics Supervisor Coordinator Circular, 2015). In the testing process, the student performs the laboratory activity before the tester, presents the results, and answers orally theoretical and practical questions. For the laboratory examination in this format, the student is required to arrive equipped with a portfolio of works that include all the activities he performed in the laboratory during his studies. The work portfolio will constitute 10% of the examination grade (Physics Supervisor Coordinator Circular, 2015).

2. Examination in Inquiry Laboratory

This test format is an *unseen* test. The student is examined on an experiment he does not know. The topic of the experiment can be from the learning topics or from a topic that has not been learned in the school. In this questionnaire the examinee must have mastered

the skills required in the physics laboratory: the examinee performs the experiment (according to the explicit directions in the questionnaire), processes the experiment's results, and draws conclusions. In the continuation of the test, the student answers in writing comprehension questions related to the experiment and the questions that address the analysis of the findings and the theory. In addition, the test-taker must answer one question from two questions that refer to the list of compulsory experiments, which are known to the student ahead of time (Physics Supervisor Coordinator Circular, 2015). Kapach (2014) maintains that although the questionnaire title is 'Inquiry Laboratory', it does not have most of the components of inquiry, such as asking an inquiry question, positing a hypothesis, and planning an experiment.

However, in both ways of examination existing in the framework of the high school matriculation examination in the laboratory physics in Israel, the regular laboratory and the 'inquiry laboratory' questionnaire, the students work with detailed briefings. Using the detailed briefing, the students are guided step by step to complete a procedure that ensures that they will reach the expected answer (Domin, 1999). In learning the laboratory in these frameworks primarily the skills of performing the experiment, analyzing the findings, drawing conclusions, and reporting in writing are expressed. The student's part in activities in these frameworks is generally summed up in the performance of the instructions in the briefing given by the teacher (Domin, 1999; Kapach, 2014).

In contrast, teaching the laboratory in the inquiry approach enables students to investigate questions that interest them and enables them to make mistakes and to learn from these mistakes and thus reveals select aspects of scientists' ways of work. In addition, this approach creates learning opportunities that enable the development of skills not expressed in traditional learning (the ways of examination existing described above in the framework of the high school matriculation examination in the laboratory physics in Israel), such as the development of the ability of an independent learner, and the development of higher thinking skills (such as asking questions, phrasing the inquiry question and hypothesis, planning the experiment, reporting an oral discussion, and sharing their knowledge with peers) (Hmelo-Silver, 2004; Kapach, 2014; Tarhan & Acar, 2007).

The following chapter presents a number of tracks in the teaching of physics in the high school in Israel, which show that the laboratory in physics is one of the possible learning environments for the integration of teaching in the inquiry approach. Learning through inquiry is meaningful learning that contributes to the development of complex skills that are not expressed in traditional learning and the development of independent learning skills.

1.2.3 Number of Tracks that Integrate Inquiry in the Teaching of Physics in the High School in Israel

Today, it is possible to find few schools in the educational system of Israel that teach in the inquiry approach in the field of physics. In education, inquiry is addressed as a supra-concept, from which a ‘family’ of educational approaches with a common denominator is derived, such as learning through inquiry, project-based learning (PBL), product-based learning, and problem solving based solutions, and so on. All the approaches involve active, experiential, and in-depth learning, related to relevant issues that interest the student. All these approaches place the student in the center and encourage meaningful processes of learning that are characterized by the structuring of knowledge through the search for solutions to problems (Loyens & Rikers, 2011). In this section, a number of different tracks that in general integrate inquiry in the teaching of physics in the High School in Israel will be presented, but will not focus on any one way or another. It should be noted that there are other different tracks in Israel not mentioned in this chapter.

PELEH² Track

The PELEH track is an initiative-based track of teachers of physics who participated in the initiatives program of Rothschild Weizmann. The PELEH track was first implemented in 2009 and it has continued until today. According to the publication document of the opening of the ‘In-Service Training for Teachers Leaders of PELEH’ (Alon et al., 2009), the goals of the PELEH track are to allow teachers to integrate in the teaching of physics diverse ways of teaching, so that the students can learn and investigate

² PELEH is an acronym in Hebrew for Physics Learned Differently. In Hebrew the word means amazing.

in an in-depth manner topics from the curriculum of physics and new topics, cultivate the students' feeling of ownership over the product they build and over the learning activities, allow different students to develop their special abilities, and develop a variety of skills that are not acquired generally in traditional teaching.

In the laboratory studies in the PELEH track, the students experience inquiry skills in activities of different types that offer a variety of levels of inquiry. Two types of activities are on the basic level of inquiry (ascending order). The first is an activity that offers inquiry skills, similar in characteristics to traditional activity, all the groups in the class perform the same experiment, although inquiry skills that are not routine in the traditional laboratory are integrated (for example, performance of an observation). The second is guided inquiry activity, in which different groups research in parallel different aspects of the same phenomenon. In this activity the teacher dictates to the students what and how to research, with the integration of new inquiry skills (which are not routine in traditional teaching, for instance, planning the experiment). There are three types of activities on the level of advanced inquiry (ascending order): open inquiry activity, mini-project, and project. In these types of activities the teacher guides the students to be partners in the shaping of the activity (open inquiry) and even shaping it totally themselves (mini-project and project). As the level of inquiry of the activities rises, the teacher less dictates and implements directly and more guides and instructs and the students are less directed according to the 'closed' instructions and more shape the activity themselves (through 'open' instructions) (Kapach, 2014).

Activities of this type obligate ongoing follow up of the student's ideas, skills, and attitudes regarding what he learned until a certain point in the learning process and not only at its end (Harlen, 2003). In the framework of this track, throughout all the years of study, the students will build a collection of works, called a portfolio, that includes continuous documentation of a wide variety of activities and learning environments that were performed in the track (such as inquiry activities in the laboratory, reading a scientific article, and scientific trips), the contents learned, and all the reflections and feedbacks of the learning process performed at different points in time by the students, his peers in the track, and the teacher (Kapach, 2014).

According to Paulson, Paulson, and Meyer (1991), the portfolio is an intentional collection of the student's works, which presents his efforts, progress, and achievements in a certain area or in a number of areas. The process of the building of the portfolio and its content needs to include the student's participation in the choice of the content, criteria according to which the items in the portfolio were chosen, criteria for the judgment of the material included in the portfolio, and evidence of the student's personal reflection. The portfolio is not a new idea, and it has been used for many years by different professionals, such as artists, photographers, journalists, and so on (Birenboim, 1997). The use of the portfolio in the learning process obligates not to address it as a folder in which the student's works are filed but as a select collection with the goal to present personal development throughout the time of the learning process and the achievements. Exactly like an artist builds a file of works through the choice of his best works, the student's portfolio can be built from the works through which the student chooses to present his knowledge (Slater, 1996).

Towards summative assessment, the student's high school matriculation examination on the portfolio in this track, the student must choose from the variety of the types of activities that appear in the file of the works two different activities undertaken through inquiry in the laboratory (at least once of them in advanced inquiry). The student will perform a presentation before an external tester from the Ministry of Education who has been trained for this. In the presentation, the student will present a description of these activities and will exhibit mastery of the skills he has acquired, from a trend to reflect the full work file and to demonstrate his development in the learning process (Kapach, 2014).

ACHERET³ Center Track

The first model of the ACHERET Center was established in the year 2006 in the Western Galilee region, at the initiative of Dr. Moshe Recih, in the framework of the Manor Kabari Association, with the support of the Galileo Fund and under the academic-pedagogical management of Dr. Amos Cohen. This center is a Jewish-Arab center that acts to cultivate inquiry work in physics in the high school. The center was established with the goal to improve the quality of the studies of physics, to encourage students of both sexes

³ ACHERET is an acronym in Hebrew meaning Multicultural Fraternity of Researchers. The word in Hebrew means other or different.

to choose the subject of physics, to develop skills of teamwork and cooperation among students from different backgrounds, to attract quality people to the teaching profession, and to change the way of teaching and learning physics in the high school in Israel (ACHERET Center Website: <http://www.acheret.org.il>).

The center built a multicultural environment, with cooperation between different schools and different populations: Jews and Arabs, religious and secular, members of the kibbutzim⁴ and members of moshavim⁵, residents of established cities and residents of villages and disadvantaged towns, immigrants and natives, young and old. This environment accepts those who are different, while performing joint inquiry in physics. In the ACHERET framework, a process of the strengthening of the inquiry learning in every school separately is performed, at the same time as a process occurs of the building of regional groups around the unifying topic of inquiry (Reich, Cohen, & Hochstater, 2009).

Students of the ACHERET Center perform research works in physics at different levels every year, with professional guidance that helps the student choose the research topic, phrase the questions, and search for the answers. The preferred way of learning in the ACHERET Center is active learning, through the performance of a whole project of investigation and discovery, which is mainly the independent work of the learner – the researcher. In this way of learning, the student is the navigator who searches for the way, while the student learns to be helped by the sophisticated navigational devices that teacher-mentor places at his disposal. In such learning, which is mainly the student's independent work, we encounter the student in a new situation: his eyes are wide open and he exclaims "Ahh", "Eureka!" Just like Archimedes (Reich, Cohen, & Hochstater, 2009).

In recent years, centers for the teaching of inquiry in physics are being established according to the model of the ACHERET Center in the Western Galilee: the Inquiry Center in Yerucham, the ACHERET Center in the Central Galilee, the Amekim ACHERET Center, the ACHERET Center in Tel Hai. In light of the demand for the in-depth inquiry learning in physics and the demand to establish centers like the ACHERET Center in the Western Galilee, a track for the training of researchers in physics was established, Archimedes Point. This track

⁴ A kibbutz, plural kibbutzim, is an Israeli rural collective community traditionally based on agriculture.

⁵ A moshav, plural moshavim, is a type of Israeli rural town or settlement, particularly once a cooperative agricultural community of individual farmers.

began in the 2013-2014 school year, at the joint initiative of Mr. Avigdor Vilnetz, Mr. Moshe Reich, and Dr. Amos Cohen. The Archimedes Point track is intended to train teacher-mentors of inquiry in physics for all the students in the high school in Israel who choose to learn physics and to allow teachers who are interested to know the new field of 'research physics'. Those participating in the in-service training learn and experience the instruction of high school students in in-depth inquiry works in physics. The training lasts for two years and is accompanied by experience in the guidance of the high school students in the performance of advanced inquiry and even the development of new fields of inquiry. Now, through the training of physics teachers and teacher-mentors of inquiry in Archimedes Point, other inquiry centers for physics are being established according to the ACHERET model: in the schools of the Druse sector, in Haifa, Tveriya, Tzfat, Binyamina – and there are more to come. The training of inquiry experts in the Archimedes Point School and the development of the curriculum for the teaching of advanced inquiry in physics are the lever that enables and leads the establishment of the track of research physics in Israel (Cohen & Reich, 2014).

To conclude, the ACHERET Center provides an opportunity for young people from different backgrounds to engage in experiential scientific research in the field of physics and inculcates in the students a learning culture that encourages research, curiosity, and critical thinking. It combines an aspiration for excellence in science and value-oriented educational processes, strengthens the studies of physics, and inquiry in the schools and in regional groups, trains in a weekly seminar teachers and teacher-mentors for teaching and learning through inquiry and inspires the growth of additional multicultural inquiry centers ((ACHERET Center Website: <http://www.acheret.org.il>).

Physics and Industry Track

The physics and industry track was implemented for twelve years, until July 2016, and was managed by the Davidson Institute for Scientific Education and the Department for the Teaching of the Sciences in the Weizmann Institute of Science. The track was intended for students who study physics in the high school, with good achievements in the studies of physics and mathematics, who are interested in technology. The goals of the track are to promote excellence among students in the physics program in the upper school, to link between the students of the high school who specialize in physics and the world of

hi-tech industries, to enable students to know the world of the scientist in industry, to instill in them theoretical and applied physical knowledge in industry, and to allow them experience in the solving of physical problems similar to those that trouble people from departments of research and development in industry (Davidson Institute for Scientific Education-Physics and Industry Website: http://davidweb.weizmann.ac.il/excellent/school_of_contemporary_science/phys-ind).

The physics and industry program operated in the framework of a regional class. Students from different schools that are found in a region come to the institute once every two weeks for four hours for two years. In the framework, the students perform, generally in pairs, a project of the development of a model that provides a technological solution to an authentic engineering problem, with the guidance of expert teachers and engineers from hi-tech. The development of the model is based on the studies of physics in the school, with the addition of advanced topics in physics studied in the program framework (for example, electro-optics). In the framework of the program studies, the students acquire thinking strategies and tools for coping with the solution to technological problems. In addition, the students learn how to implement ideas of creative thinking for the solution of technological problems in general and in industry in particular (Langley, Arieli, & Eylon, 2010).

During their work, the students prepare a portfolio that summarizes the process of the work and its outcomes, submitted as their product. Significant parts of managerial communication, the presentation of tasks, and the handing in of works are performed online, in a unique forum and through email. At the end of the program, the students are examined orally on the project they performed by examiners of the Ministry of Education and also respond to two questions in writing on the material learned in the course framework, according to the syllabus handed out ahead of time (Website of the Department for the Teaching of Sciences at Weizmann Institute for Science – Physics and Industry: https://stwww1.weizmann.ac.il/?page_id=733).

The participation in the ‘Physics and Industry’ Program constitutes an enjoyable and empowering experience for the students. The participation in the ‘Physics and Industry’ Program entails the investment of time and effort, but it gives an opportunity for the learning of contents, tools of thinking, and technological skills that impel the student forwards toward a professional future in a variety of areas (Langley, Arieli, & Eylon, 2010).

The students who participate in all the tracks noted above, which meet the requirements of the program, are examined on their inquiry project, receive a final score from the Ministry of Education of the State of Israel. This score takes the place of two tests from the framework of the five units of study in physics – ‘laboratory’ and ‘radiation and material’. The exemption from the tests does not grant the students an exemption from attendance in the lessons, performance of ongoing tasks, preparation of laboratory reports, and participation in the class tests. However, a class teacher releases the students from assignments or tests, according to his judgment (Physics Supervisor Coordinator, 2016).

Physics and Medicine in Industry Track

The program of Physics and Medicine in Industry began as an initiative of the Two District Center for Gifted in the Oranim Academic College of Education, under the auspices of the Department for the Gifted and Excellent Students in the Ministry of Education and the Weizmann Institute of Science. The goal of the program is to bring the gifted and excellent high school students who study in the physics program closer to unique studies that combine physics and its implementations in medicine and industry. The program is intended for excellent students in the tenth to twelfth grades and enables exposure to ways of thinking and areas of knowledge relevant for the performance of a project that includes research and development in the fields of medical physics. The program enables the learners to cope with current challenges, has the students meet researchers and engineers and innovative developments, instills physics-medical knowledge, and enables experience in physical problem solving in the fields of medicine and human assistance (Krupnik-Gottlieb & Cohn, 2015).

In the framework of the program, the students perform a project in which they research a phenomenon in the field of medical physics. The students choose a technological problem in the medical aspect, learn the relevant physical background, analyze possibilities of solution, choose ways for realization of the selected solution, perform appropriate experiments, and last build a model or an ‘acting model’. The development is based on the studies of physics in the school with the addition of advanced topics in physics taught by the teachers from the college and enrichment in the field of medicine (mainly medical diagnosis). In addition, several concentrated days that include trips to industries, hospitals,

and research institutes are held. In these trips the students are exposed to the manufacturing of advanced medical devices, different types of medical diagnosis devices such as X-ray, CT, MRI (Magnetic Resonance Imaging), and so on (Website of the Course of Physics, Medicine, and Industry: <http://mofetnet.macam.ac.il/course/Default.aspx?id=3563>).

During their studies and work, the students prepare a portfolio that documents the work, which is also submitted as a part of the product of their work. At the end of the program, the students are examined orally on the project they performed, by testers of the Ministry of Education (external assessment as a part of the high school matriculation examination) and in addition are examined in writing (internal assessment) on the material learned in the program. The 'physics and medicine in industry' program constitutes an example of a successful model of meaningful learning for the empowerment of excellent students (Krupnik-Gottlieb & Cohen, 2015).

Ilan Ramon Center for Physics-Loving Youth Track

The Ilan Ramon Center holds extensive study activity in physics and astronomy with emphasis on the experiential learning and scientific experience. The center offers students scientific projects that enable young people to be exposed to the field of physics while utilizing the modern laboratories, which include a planetarium and sophisticated telescope. The projects are research-oriented and intended for high school students who learn in the physics program. The projects are performed in groups of two-three students under the guidance of academics from the Department of Physics at Ben-Gurion University, the Sami Shimon Academic College of Engineering, and hi-tech company people. The projects are in a wide variety of topics, such as superconductors, amorphous materials, NMR – nuclear magnetic resonance, biophysics, magnetic hydrodynamics, multiphase thermal turbulence, radioactive radiation, and so on. To complete the project, every group must present the work to an examiner and submit the experiment report (Ilan Ramon Center Website: http://in.bgu.ac.il/ilanramon/Pages/2_points_project.aspx).

1.3 The ‘Research Physics’ Program for Students

The ‘Research Physics’ Program is a new official program that has been approved by the Subject Committee. The program aims to improve the different initiatives for the integration of inquiry in the teaching of physics (which were mentioned above) and to assemble them under one framework. The goal is to provide these initiatives an appropriate place in the teaching of physics and to encourage the students to produce inquiry project of a high level, at the scope of five units (The highest level in high school). This chapter will describe the rationale and goals of the ‘Research Physics’ Program for the students, the target audience, the time framework, and the structure of the program.

1.3.1 The Rationale of the ‘Research Physics’ Program and Its Goals

The ‘Research Physics’ Program is an opportunity to produce return for the student, for the teacher and for society at large. On the level of the student, Although the student has the possibility of doing an ‘inquiry project’ in the framework of the physics studies, when this project is of a limited scope (two units in the framework of five units in physics), it becomes clear that this is not satisfactory according to the students, the teachers, and the entire educational system. The great effort invested in the Inquiry Project does not produce a real return in the student’s high school matriculation certificate and in the recognition of the institutions of higher education. Consequently, it is harder to recruit students to perform projects and engage in scientific inquiry (Draft Letter to the Subject Committee before the Discussion on the Research Physics Program Written by Dr. Tzvika Arika and Zeev Krakover and the Steering Committee, 2016). Therefore, the Physics Supervisor Coordinator of the Ministry of Education, Dr. Arica, along with the Steering Staff, formulated a program called ‘Research Physics’ at the scope of five units of study (in addition to the five units that exist in the studies of physics), so that the students will receive a more significant recompense for their research work.

On the level of the teacher, it can bring a new spirit into the teaching of the subject. Physics teachers develop during their career in pedagogical terms but in scientific terms they stay in place, since they repeat the same basic chapters of content, with a syllabus that has barely developed over many years. The possibility of integrating research may open

for them periodically a window into additional chapters of physics, into real engagement in physics. Furthermore, the guidance of the research will cause the teachers to diversify their ways of instruction. For the teachers, leading inquiry project will intensify them as physicists, strengthen their connection with the students and will promote the traditional instruction in all of their frames of work. Leading an inquiry project will contribute an enhancement of positive feelings towards the teaching profession and will strengthen the teachers' status. Also, this program will contribute to assimilate inquiry-based teaching in physics studies.

On the level of society, the program will train graduates who underwent a significant experience of independent learning and research and thus will instill in them the tools necessary for integration into the advanced society of the 21st century (Draft Letter to the Subject Committee before the Discussion on the Research Physics Program Written by Dr. Tzvika Arika and Zeev Krakover and the Steering Committee, 2016). The 'Research Physics' Program for students is a unique and prestigious program, which opens for the students a window to the world of scientific research. This is for the raising of interest of the students in physics, for the inculcation of the research knowledge for more students, for the cultivating of the learners' responsibility, as well the encouragement of creativity, initiative, and imagination of the students. It enables the students not only to recognize the discipline but also to understand what to do with it in actuality. It enables them to structure their learning, at a pace suitable to them, with greater depth of understanding. It provides a solution for students who are missed by the learning style accepted in the teaching of physics. It develops among them abilities of independent learning, coping with problems, analysis of complex problems, and creation of solutions that will allow them to act under conditions of uncertainty, which are the clear characteristic of the present and future eras.

In the inquiry physics environment, there is the potential for the promotion of the students' learning and for the increase of the depth of their understanding of the scientific concepts and understanding of the nature of science and to transform the student into an independent inquirer possessed of initiative. The aim is to promote the assimilation of inquiry learning in the teaching of physics (Letter to School Principals on the Dissemination of the 'Research Physics' Program, Ministry of Education, 2016).

Students in “Research Physics” program will experience physical issues by using the inquiry method. Inquiry learning, in the field of physics, requires expertise in the field of content and an understanding of physical processes and physical principles. Simultaneously with other skills such as units of physics and mathematics unique according to the subject of the inquiry; inquiry method and research statistics; scientific writing, reading and analyzing academic articles; advanced computer skills; the history of physics emphasizing researches, experiments, discoveries and inventions; and more. In this way, the students will be able to study intensively subjects from the school program, to learn new subjects (outside of the school program) and to develop a variety of practices acquired by inquiry. The implementation of inquiry project invites the fostering of learning skills in the field of content and in the field of scientific research. Additionally, connects the profession of physicist to the modern cultural space and permits an integration between the field of physics and other fields. The subject of the inquiry should be actual and on the forefront of research in the world (Draft Letter to the Subject Committee before the Discussion on the Research Physics Program Written by Dr. Tzvika Arika and Zeev Krakover and the Steering Committee, 2016).

1.3.2 The Target Audience of the Program

The target audience of the program consists of students with motivation, who learn in the physics program on the level of five units of study in the high school (highest level of physics studies in the high school in Israel). The required scholastic level emphasizes cognitive skills as well as theoretical and applied knowledge on the highest level. The research in physics requires a significant background in physics, and therefore this program cannot come in place of the study of physics at the level of five units but is in addition to it, at the level of another five units. Parallel learning of physics at the level of five units is a necessary condition for participation in the ‘Research Physics’ program (Letter to School Principals on the Dissemination of the ‘Research Physics’ Program Written by the Supervisor Coordinator, Ministry of Education, 2016).

1.3.3 ‘Research Physics’ Program for Students in the Davidson Institute of Science Education in the Weizmann Institute for Science (Research Field)

1.3.4.1 Description of the Program

The ‘Research Physics’ Program for Students in the Davidson Institute of Science Education in the Weizmann Institute for Science began to be implemented in 2016. The program is proposed for students as a program that is ‘outside of the school’, in other words, as a program that operates in the afternoon outside of the school walls. Since in every class there are only a few students who are interested in performing physics inquiry, it was necessary to collect small groups of students from a number of schools. Therefore, students who chose to learn in the framework of ‘Research Physics’ in the Davidson Institute come from different schools and become a mixed group, a regional class, for a total of about 20-35 students in the class (the current research investigated a group of students of the second cycle, throughout the program period 2016-2019, 34 students).

The main work of the students is supported by teacher-mentors and experts in teaching through inquiry. Each teacher-mentor is guiding a pair of students during their project. It should be noted that the program teacher-mentors are not the teachers of the students in the school. The fact that most of the teachers who teach physics in the high school are not expert in teaching through inquiry (Kapach, 2014) dictated the need for the support of the expert teachers. So, the teacher-mentors received training in a workshop, which took place in form of a community of practice (Grossman et al., 2001) at the Weizmann Institute. There they learn how to integrate inquiry-based teaching into the classroom and receive support for ongoing work throughout the inquiry process by pedagogical and academic coordinators. The participants share their experiences, raise difficulties and dilemmas that arise during working with students, and discuss with peer teachers and with coordinators about these difficulties and dilemmas.

In the framework of the program, the students receive opportunities for the performance of physics inquiry at different levels of guidance (structured inquiry, guided inquiry, open inquiry). The guidance is focused on the student – it is for a pair of students. The learning environment of the program encourages diverse learning methods such as independent learning, active learning, cooperative learning, peer learning, and online

and/or computerized learning. The physical environment in which the students are found is a technology-intensive laboratory in the Davidson Institute, rich in sophisticated laboratory equipment. As well as laboratory staff, acting in full cooperation with the teacher-mentors and students. The aim is to allow students to conduct experiments / build projects that are complex relative to the regular laboratory in the high school.

The framework of the program is for three years: in the tenth grade, once every two weeks for about four hours and in the eleventh and twelfth grades once a week for four hours. In this framework, the students will carry out inquiry activities of various kinds (structured inquiry, guided inquiry, open inquiry) and at different scopes, culminating in a wide-scale project.

At the beginning of the tenth grade, the physics students are at the beginning. Therefore, at this stage the teacher should include activities with the goal of connecting them to the program and making them like it, activities and experiences that will provide stimuli, cultivate curiosity, and encourage creativity. In addition, they should have activities that will develop in the students independent learning skills, coping with problems, analysis of complex problems, and creation of solutions that will allow them to act under conditions of uncertainty so that they can anticipate the future (focused on the program's goals). These are activities that have analysis of research and that engage in skills that the school will require of the student in the continuation. Generally these are short-term activities that end in one or two sessions. During every activity, the students in the program are helped by teacher-mentors as support for their independent work.

In the continuation of the tenth grade or the beginning of the eleventh grade, it is possible to go a step higher and include a series of slightly more challenging and long-term activities. At a certain stage a process of exposure to the different research subjects and current subjects will begin, and then there is the choice of the research topic. The steering committee of the program recommends that the student's own research will be conducted from the middle of the eleventh grade until the end of the first semester of the twelfth grade. In this period, there will be intermediate evaluations and changes will be introduced as necessary. In this time there will be the initial writing of some of the chapters of the work and the experiences in the presentation of things orally. At the end of the first half of the twelfth grade, there will be a last round of experiments and updates, the final drawing of

conclusions, and even the first version of a full work. There will also be intermediate evaluations at dates that will be determined by the entire staff ahead of time (From the Letter of the Steering Committee of the Program to the Subject Committee).

The tasks that the students will submit and the ways of evaluating them will be diverse throughout all three years of the studies. At the end of the studies the students will submit their research work and their research project file (in which there will be all the products, such as laboratory reports, portfolio file), which constitutes a main and important component. Last, the students will be examined in an oral examination by a tester from the Physics Supervision of the Ministry of Education in Israel (From a letter to the School Principals on the Dissemination of the 'Research Physics' Program Written by the Physics Supervisor Coordinator, Ministry of Education, 2016).

1.3.4.2 Design Guidelines - The Principles of the Cognitive Apprenticeship Paradigm – Structuring and Problematizing

The instruction methods of "Research Physics" program adopt the principles of cognitive apprenticeship- instruction that situates the learner in authentic situations, where the learner works with a trained expert who guides the learning process. This includes the development of perception through authentic and continuous activity that supports learning that enables the students to acquire, to develop, to use cognitive instruments in the authentic space and the system of relationships with the expert is an important component in the learning process (Collins, Brown, & Newman, 1989).

According to Collins et al. (1989), in the model of cognitive apprenticeship the learner accepts the commitment to the learning process, experiences actively the performance of the assignments, cooperates with peers, and holds a constant and continuous dialogue with the instructor. Use is made of 'cognitive' – since the techniques of apprenticeship shift from physical skills to cognitive skills. In the apprenticeship, the students become like experts and develop a conceptual understanding through the social interactions and cooperation with the culture that belongs to the field.

The stages in the process of cognitive apprenticeship according to which teachers and coaches advance the learning (Collins et al., 1989; Collins et al., 1991):

1. Modeling. The teacher helps the students make their knowledge explicit through her strategic illustrations for students in the framework of authentic activity. In other words, the teacher illustrates her work and externalizes her ways of thinking.
2. Coaching. Feedback for the student on his ways of work relative to the expert. In other words, the expert supports the students' attempts to carry out the task and provides scaffolding that will help them, when the student's role is to examine himself relative to the expert.
3. Fading. Distancing and support from a distance. The teacher gradually reduces her support and increases the levels of freedom, empowers the students, and directs them to continue independently and thus enables the students to cultivate their self-autonomy and to solve problems independently.

From this approach, it is possible to derive the principles of the design of the instruction "Research Physics" program, and will serve as a basis for the construction of the intervention of this program. The above principles attribute considerable importance to the context in which the knowledge is learned and attempt to "acculturate" the students into authentic activity in a rich context – like the problems that are encountered in scientific research. In the way of cognitive apprenticeship, the teacher serves as a mentor for the students, through the use of authentic activity from the field as a meaningful part of the learning, and the student learns to take part in the world of the scientist/researcher.

Frequently, the problems found in the research are too complex and open for the student, and it is necessary to have scaffolding for the learners in the complicated tasks. In other words, it is necessary to provide supports that enable the students to handle the requirements and skills that are more complex than what they could tackle by themselves. Reiser (2004) proposes two mechanisms of scaffolding in the student's work: structuring and problematizing.

Structuring is the creation of a change or addition in the structure of the task in order to reduce the cognitive load so that the student can cope with the task according to his previous knowledge. For instance, *decomposing complex tasks* is the disassembly of a complex task into sub-tasks that can direct the learner to which actions to adopt, their order, or necessary aspects in the process. *Focusing effort* is the reduction of a number of steps/possibilities, choosing ahead of time data or removing more routine parts of the task, in order to help the learners focus the resources and their learning. *Monitoring* is "explicit

structures such as prompts, agendas, or graphical organizers can help learners keep track of their plans and monitor their progress” (Reiser, 2004, p. 284).

Problematizing involves “(a) focusing students’ attention on an aspect of a situation that needs resolution; (b) eliciting students’ commitment of attention and resources to reasoning about an aspect of a problem; (c) creating interest in some aspect of a problem or getting students to care about understanding or resolving an issue” (Reiser, 2004, p. 287). Problematizing needs to be performed in a way that challenges the student and presents to the student a problem that requires a solution, but not in a way that simplifies the problem too much and keeps it only to carry out the teacher’s instruction.

The concept of problematizing is slightly opposite from the concept of structuring, and they complement one another. On the one hand, this is the building of tasks and making them more applicable for the students, while on the other hand this is the shaping of tasks for the learners in ways that make the solving of their problems more productive. It is difficult to achieve balance between the structuring and the problematizing when planning scaffolding tasks. The presentation of overwhelming complexity without structuring does not lead to problematizing on the topic, since the student does not have the instruments to handle this complexity. On the other hand, a task that does not have a certain complexity and guides the students algorithmically may not allow the students to engage in coping with the problem and with the complexity of the problem solving. Therefore, the achievement of both of them makes the work into meaningful learning.

Accordingly, during the investigation in the Research Physics Program, to help the students externalize their work processes and develop their problem solving abilities, on the one hand the students are allowed to perform tasks that are not trivial for them, that are challenging and meaningful. The activities in this program give the students the opportunity to identify the problem and define it, to propose a method for solving the problem, to overcome the ‘obstacles’ during the search for the solution, and to examine the result of the problem solving. On the other hand, the teacher-mentors carry out scaffolding activities – structuring and problematizing, which help in the building of the task of the problem solving, ask powerful guiding questions, direct the students’ attention to actions that the students are not aware of (for instance, separation of variables, choice of measurement instruments, comparison of an experimental model to a theoretical model, control of the

results, and analysis of the data), and provide feedback for the students' work orally and in writing, including formative assessment throughout the inquiry process. The scaffolding can help the students deal with the challenges they face during the inquiry work, support the students' learning, shape the students' performances and their understanding of the inquiry, both in terms of the content and in terms of the inquiry practices. In addition, these actions will help the students externalize the process of their work and generalize it for future research. In other words, the teacher's scaffolding supports the students so as to solve the problem with which they cope at the moment and help them generalize the experience and develop their ability to solve similar problems in the future.

The structure of the intervention of the Research Physics Program (see the table below in section 1.3.4.3) was planned following the paradigm of cognitive apprenticeship (Collins et al., 1991). The process includes the modeling of the task explicitly for the students, practices, and suggestion of a scaffolding for the management of the different tasks and last a gradual withdrawal from the scaffolding in order to increase the learner's independence. Accordingly, activities of the preparation stage were planned gradually: the first tasks of the preparation stage focused on certain inquiry practices and therefore were planned for the short term, which lasts four to ten hours. Every activity presented to the students measurement instruments or a different data analysis in order to provide the students with an arsenal of instruments they can use to perform the project for the long term next year.

According to the approach of cognitive apprenticeship, through the withdrawal of the teacher-mentor's scaffolding, two additional activities were carried out in the preparation stage: a semi-open inquiry on the topic of springs and the 'mini-project' open inquiry, which were intended to increase the levels of self-regulation and decision making of the students. During the first months of the eleventh grade (about 30 hours) the students engaged in the building of computational models on physical phenomena in the method of Euler and with the programming language of VPython. Through computational models, the students can research complex processes that it is impossible/difficult to describe in mathematical formulae, as control for advanced experiments and to compare the results to what occurs in the real world, to predict even greater environmental processes (Chabay & Sherwood, 2008). After the end of this stage, the students went through a process of the choice of the phenomenon and inquiry research project (possible phenomena for projects were proposed

primarily by the academic coordinator of the workshop and were presented before the students. The students chose the phenomena they sought to research and the development staff adjusted between the teacher-mentors, the students, and the project phenomenon). As described previously (section 1.3.4.1), during the entire inquiry work every pair was guided by the teacher-mentor who participated in the professional development workshop of the Weizmann Institute. The pairs of students began to work on their projects for the long term for about a year and a half, about two months after the start of the eleventh grade and until the end of the twelfth grade. The students began to work on their projects for the long term for about a year and a half, about two months after the start of the eleventh grade and until the end of the twelfth grade. The students engaged in the planning and the performance of the inquiry in a learning environment similar to the environment of the scientific researcher and ended with an oral presentation before the teachers-mentors and their peers and submitted a written inquiry work. The way was cognitive apprenticeship from the beginning of the investigation until its end – in other words, the teacher serves as a mentor to his mentees, through the use of authentic activity from the field as a meaningful part of the learning, and the student learns to take part in the world of the scientist/researcher.

1.3.4.3 Intervention Structure of the "Research Physics" Program - Activities and components of the inquiry carried out in each activity in the learning sequence

The following table presents a list of activities (first column) held in the “Inquiry Physics” Program for the students throughout the three years (tenth to twelfth grades). In each one of the activities the inquiry components that the students used during the activity are noted (from the observations of the meetings and the looking at the students’ learning products). The following table describes the learning continuum, activities and inquiry components in each activity: in the preparation stage in the tenth grade and the start of the eleventh grade (tenth grade activities: 1-6, eleventh grade activities: 1-2), when in this stage the students did not have a close teacher-mentor and the partner was not constant (changed from activity to activity); in the intermediate stage in the eleventh grade (eleventh grade activities: 3-4); in the final stage of a long-term inquiry project work in the twelfth grade (twelfth grade activities: 1-2). When in these stages every pair of students had a close teacher-mentor and the work was with a constant partner from the start of the project work until its end.

Table 2: Activities and Components of the Inquiry in Each Activity in the Learning Sequence of the "Research Physics" Program (Sigron, M)
 (✓= most of them, Some=some of the students, not most of them, _ = none of them)

Skills Activity	Choosing a topic	Locating data sources	Phrasing goals/questions	Planning an experiment (Including isolate variables)	Performing an experiment	Data processing	Drawing conclusions (Including a comparison between theory and experiment)	Oral report	Written report	Building content knowledge-Independent learning of theory	Building a theoretical model
10th grade-1: A trolley at a fixed speed (One meeting 11/2016)	-	-	-	-	✓	Some	-	Some	✓	-	-
10th grade-2: Falling of a magnet (One meeting 12/2016)	-	-	-	-	✓	✓	Some	Some	✓	-	-
10th grade-3: Atwood machine (Two meetings 1/2017)	-	-	✓	Partial planning	✓	✓	✓	Some	✓	✓	Some
10th grade-4: Roemer experiment (Two meetings 2/2017)	-	Some	-	-	✓	✓	Some	-	✓	✓	-
10th grade-5: Investigation of springs (Two meetings 3/2017)	✓	Some	✓	✓	✓	✓	✓	✓	✓	Some	Some
10th grade-6: Mini-project (Four meetings 4-6/2017)	✓	Some	✓	✓	✓	✓	✓	✓	✓	✓	Some

Skills Activity	Choosing a topic	Locating data sources	Phrasing goals/questions	Planning an experiment (Including isolate variables)	Performing an experiment	Data processing	Drawing conclusions	Oral report	Written report	Building content knowledge-independently	Building a theoretical model
11th grade-1: Computational modeling (Structured activities) (Seven meetings 9-10/2017)	-	-	-	-	-	✓	✓	-	✓	Some	✓ Computational modeling
11th grade-2: Summative task in computational modeling (Two meetings 10-11/2017)	-	-	✓	-	-	✓	✓	-	✓	Some	✓ Computational modeling
11th grade-3: Work on the project until submitting an intent document 5/2/2018 (Twelve meetings 11/2017-2/2018)	✓	Some	Some	Some	Some	Some	-	-	✓	Some	Some
11th grade-4: Work on the project until submitting a midterm report (Twelve meetings 2-6/2018)	✓	✓	✓	Some	✓	✓	✓	✓	✓	✓	Some

Skills Activity ⁶	Choosing a topic	Locating data sources	Phrasing goals/questions	Planning an experiment (Including isolate variables)	Performing an experiment	Data processing	Drawing conclusions (Including a comparison between theory and experiment) ⁷	Oral report	Written report	Building content knowledge-independently	Building a theoretical model ⁸
12th grade-1: Work on the project until submitting an intent document 31/12/2018 (Eleven meetings 10-12/2018)	✓	Some	✓	✓	✓	✓	✓	-	✓	✓	Some
12th grade-2: Work on the project until submitting a summary report (16 meetings 1-6/2019)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
The stages of the program	Preparation Stage			Intermediate Stage				Final Stage			
Activities at every stage	10th grade:1-6, 11th grade: 1-2			11th grade:3-4				12th grade:1-2			

⁶ A brief description of activities, see the Appendix 2.1

⁷ The component of drawing conclusions addresses in the program different aspects: the experimental model, comparison between the experimental model and the theoretical one, and examination of the comparison in the context of measurement error. The intention in the program is that the students will understand the following. In physics it is necessary to differentiate between theory and experiment and general theory can be examined in an experiment in a given system.

⁸ A theoretical model is the finding of a relationship between variables on the basis of the implementation of general physical laws in the given system (problem solving). An experiment model is measurement of the relationship between variables in the given system and it is different from the theoretical model. Comparison between a theoretical model and an experimental model in a given system enables better understanding of the components that influence the experimental system. And comparison between a theoretical model and an experimental model in a given system enables general physical laws to be confirmed.

2. Research Methodology

2.1 Research Design

The paradigm of this research study is post-positivism, since the research proposed here is based on the beliefs of the post-positivist paradigm in the three issues: ontological, epistemological, and methodological (Guba & Lincoln, 1994, 1998, 2005).

The belief in the ontological issue in the post-positivist paradigm. This addresses the nature of the researched world and what can be known to us in reality, in the nature of the investigated world. What is reality? Is it possible to truly know what the nature of things in reality is and how things work? What in essence can be ‘known’? Critical realism – there is a true reality but there are great chances to perceive it in an imperfect way. In other words, this paradigm maintains that there is one reality that the senses perceive partially.

The belief in the epistemological issue in the post-positivist paradigm. This addresses the assumptions regarding the researcher’s ability to understand the researched world and the entire system of assumptions that the researcher holds that pertains to his knowledge status – what is the nature of the relations between the ‘knower’ (the researcher) and what is possible to know? or in other words between the learner and what is learned. What is the place of the researcher in the research story? The researcher is not perceived as disconnected from the topic he learns. He is always positioned in a certain system of values, from which he observes and interprets. The researcher is aware of his subjective positions and his values and attempts to be objective as possible. In other words, there is the likelihood but not the certainty of the correctness of the findings.

The belief in the issue of the methodology in the post-positivist paradigm. This addresses the method, including the principles, methods of action, laws, and assumptions that the research is based on. How will the researcher discover what can be known? The manipulative experimental designs are ‘improved’ (less laboratory like). Post-positivism enables integration of quantitative and qualitative research instruments. Indeed, in this research there is a mixed methodological approach that combines qualitative and quantitative research methods.

2.2 Project Aims

The aim of this descriptive research is to portray the students' perception of the processes that they undergo in the 'Research Physics' program during the different stages of the three-year program, in particular:

1) To portray the students' perceptions with regard to the different inquiry practices they have experienced, challenges they have faced, and their development in these inquiry practices, and to identify the relationship between development, experience, and challenge.

2) To map their views with regard to the inquiry process and to the learning environment in which they operate in the 'Research Physics' program (e.g. roles of students and teachers and learning resources provided). In particular, their view of the affordances and barriers of this learning environment to the completion of their research work and their personal growth.

2.3 Research Approach

The research aims to examine students' reflections and opinions of their experience of inquiry practices in a 'Research Physics' program, that enacts structuring and problematizing design guidelines (chapter 1.3.4.2).

The research approach is descriptive (systematic description of the characteristics of the phenomenon studied); developmental (describing the changes in the researched phenomena in the different stages of the three-year program) and phenomenological (in that it focuses on the commonality of the experience within the group of participants in the 'research physics' program). In particular, the study examines the relationship between students' experience and challenge in performing inquiry activities and students' perception of their development in various inquiry practices as well as their view of the inquiry process and the learning environment in the "Research Physics" program.

In the present research study, use was made of the triangulation approach. In this type there is mixed methods research approach, which combine elements of the qualitative and quantitative research approaches (Johnson, Onwuegbuzie, & Turner, 2007) (see further explanation in subchapter 2.5). This research was performed in triangulation of the findings, in which the consistency of the findings is examined through diverse methods of

the extraction of quantitative and qualitative information, and in this way complementary aspects of the same phenomenon are described. The assumption is that a single method cannot illuminate any phenomenon perfectly and that through triangulation the weaknesses of one research method will be compensated by the strengths of the other research method, thus facilitating a greater depth of understanding of the phenomenon (Denzin, 1978; Patton, 1990). The qualitative research method helped to characterize the experiences and enrich the evidence and the interpretation of the quantitative research, when the researcher has sensitivity and ability to absorb and clarify implicit situations and according to them to develop insights that will facilitate the analysis in a guided and focused manner the research participants' perceptions (Sabar Ben-Yehoshua, 1999; Shlasky, 2008).

In particular, the study examines the relationship between several variables. The independent variables are the perceptions of the students of the extent they have experienced of various inquiry practices and the challenge they have faced in these practices while performing inquiry activities in the 'Research Physics' program. The first dependent variable is the students' perception of their development in performing inquiry practices during the program. The inquiry practices focused on 15 components: Choosing a topic, locating data sources, Phrasing goals/questions, Planning an experiment, Performing an experiment, Using technological aids and a computerized laboratory, Data processing, Building a theoretical model, Drawing conclusions, Written reporting on the inquiry, Oral reporting on the inquiry, Building content knowledge, Self-regulation, Teamwork with the partner, Teamwork with peers in the broader group. In addition, another dependent variable is students' view of the inquiry process as a whole, and their opinions with regard to the learning environment in the "research physics" program (e.g. the roles of students and teacher-mentors, the learning resources provided, and how this learning environment contributes to them in performing the research work and their personal growth). While the research aspires to achieve for each one of the respondents information about each one of the variables, because of the small sample size and because each of the above variables is tested differently (some quantitatively and some qualitatively or quantification of qualitative data), the relationship between the variables is examined in terms of means and not correlations.

This research study is not an experimental research, since the research study measures the level of performance that the respondents achieved without dependence on the manipulation, since the program is implemented in the institution regardless of the research. Despite the clear advantages of the experimental research design which is held in a laboratory (which enables more exact conclusions), where the researcher has full control over the variables, sometimes it is not similar to what happens in reality. The correlative research is closer to the conditions of reality, so it is possible to examine the research questions in the natural environment where the behavior occurs – at the expense of the control of the variables (Beyt Marom, 1990).

This descriptive research describes the processes that the students undergo in the ‘Research Physics’ Research’ for 3 years. Follow up was performed on the students for the duration of their years of studies in the program at different time intervals (preparation stage, intermediate and end final stage). The research approach will be based on the students’ self-reporting (questionnaires and interviews), accompanied by observations of the program sessions. The self-reports are examined in light of the observations in the field and the way in which the intervention (the program) was performed. The research describes events that occur in the ‘Research Physics’ environment, the students’ opinion of the learning and the teaching along the inquiry activities at various stages of the “Research Physics” program. Survey researches and developmental researches were performed, intended to answer research questions in this context. Through the survey researches, we obtained detailed information on attitudes, intentions, through developmental researches – longitudinal researches examined changes in behavior over time.

Note that the students were asked to fill in their names in a questionnaire, since this is a group of students who volunteered to participate in the study (with parental consent see appendix 2.5), they are in fact members of the research community. Thus, the students will probably respond seriously, in a caring manner, and take responsibility for their words. In addition, being members of the research community, students are usually interested in fully cooperating and speaking honestly, because they also are interested in the benefit of research. The students know that anything related to their identity is confidential and used just to the research needs, and they are aware that their honest opinion is important for research. This type of research gives place to the voices of the participants in the study, in order to get a bottom-up explanation from the participants' answers. In this way, it enriches the research information and helps to obtain vital knowledge that is directly related to the improvement of learning and teaching through inquiry.

2.4 Research Problem

1) How did students' perception of their development relate to their perception of the experience and challenge in performing various inquiry components⁹ along the stages¹⁰ of the 'Research Physics' Program?¹¹

In particular:

- A) Students' perception of their **experience and challenge** in each stage of the program:
- To what extent did students experience each of the inquiry components?
 - To what extent did students find these components to be challenging for them?
 - What are the challenges that students identify they have faced and what means did they use to cope with them?
- B) Students' perception of their **development** in each stage of the program:
- To what extent did students develop in each of the inquiry components?
 - What aspects of the inquiry components do student believe that they have developed and what are the causes for this development?
- C) **Students' development, following experience and challenge** in each stage of the program:
- How did the extent of the students' development in the various inquiry components relate to the extent of experience and challenge in these components?
 - How do the experiences, challenges, and development, as perceived by the students, correspond to the observed experiences, challenges and development?

2) How did student perceive **the learning environment** in the 'Research Physics' program along their engagement in the various stages of the inquiry work?¹² In particular: roles of students and teachers and learning resources

⁹ In 15 components of inquiry: Choosing a topic, Locating data sources, Phrasing goals/questions, Planning an experiment, Performing an experiment, Using technological aids and a computerized laboratory, Data processing, Building a theoretical model, Drawing conclusions, Written reporting on the inquiry, Oral reporting on the inquiry, Building content knowledge, Self-regulation, Teamwork with the partner, Teamwork with peers in the broader group.

¹⁰ Stages of the program: a preparation stage for the inquiry project, an intermediate stage and a final stage of inquiry work (see chapter 1.2.4.3- Intervention Structure of the "Research Physics" Program

¹¹ Quantitative & Qualitative instruments: Preliminary questionnaire, Inquiry skills questionnaire, Summative questionnaire, Observation of the students' activities

¹² Quantitative & Qualitative instruments: Attitudes questionnaire, Summative questionnaire, Interviews

The **research assumptions** regarding the above two questions (in the quantitative sub-questions) are that the students' experience and challenge in the inquiry activity in the program 'Research Physics' will affect:

- 1) The students' development in the ability to perform inquiry work (in various inquiry components)

The research assumption about the first research question is that the degree of experience or degree of challenge that the students experience in the inquiry components in the program will influence the degree of development of students in these components. In particular, as the students will experience the inquiry components in the program and will cope with the challenges innate in their performance, the development will be more significant.

- 2) The students' views with regard to the inquiry process and to the learning environment in the 'Research Physics' program (e.g. the roles students and teacher-mentors and the learning resources).

The research assumptions about the second research question:

- i. The 'Research Physics' environment was designed to be fundamentally different from the school laboratory activity in the following aspects: (A) The tasks that the students must perform are defined ambiguously regarding the tasks of the teaching laboratory. As a result, the student is more involved and active in the learning process (building the knowledge) and the search for the solving of tasks. (B) The division of the responsibility between the teacher and the student assigns to the latter more responsibility than the teaching laboratory – the focus of the definition of the problem, the location of the resources for the coping with it (both theoretical and experimental), and management of the inquiry work as a whole. (C) The environment that is similar to the world of the scientific research, both in terms of the learning resources that can be given to the students (equipment, time, instruction) and perception of the laboratory, its ways of execution and its goals. Accordingly, the expectation is that the students will identify these differences as prominent differences.

ii. Learning through inquiry increases the chance among the students to develop positive attitudes towards science (Ogens, 1991)- attitudes that reflect the epistemology of authentic scientific research, interest and evaluation towards the scientific research approach. The main way to achieve this goal is to engage the students in inquiry activity that addresses authentic problems, which reflect well the epistemology of real scientific research (Chinn & Malhotra, 2002). Research indicates that the students' attitudes depend on the students' degree of involvement and active participation in learning; as the students are more involved and independent in their inquiry, they develop more positive attitudes towards science (Ornstein, 2006). The 'Research Physics' Program situates the learner in authentic situations (selected from a reservoir of topics), in which the learner has to be involved and active in learning and in management on the inquiry work. The activities in this program give the students the opportunity to identify the problem and to define it, to propose a method of the solution of the problem, to overcome obstacles during the search for the solution, and to examine the outcome of the solution. The student learns to take part in the environment of an authentic research. Accordingly, it is reasonable to expect that the students will express positive attitudes on the inquiry process and on the "Research Physics" learning environment as they advance in the stages of the program and they will find changes for the better in most of their attitudes between the final stage and the previous stages of the inquiry work. In particular, when the active experience in the inquiry will lead the students to understand the nature of the inquiry process and the dynamism it entails, to learn the areas of responsibility and independence in the inquiry work and under its management, to know the value of ways to build knowledge and search for evidence and solutions (such as independent and active learning, teamwork, and cooperative learning with the project partner and with peers in the broad group, creative thinking for finding solutions to problems that appear in the inquiry process, and to leave from situations of uncertainty), and to display interest and curiosity for the studies of science and for in inquiry in particular. In addition, it is reasonable to expect positive attitudes on the students' part regarding their ability to perform the inquiry work and the contribution of the program to their performances and especially in the feeling of self-efficacy to perform inquiry in the final stage of the inquiry process.

iii. The Research Physics Program is a new program in the education system in Israel, and the students in the program were instructed by teacher-mentors, who participated in parallel in the training program for the instructors of teacher-mentors of research physics. In other words, most of the teacher-mentors are novices as instructors of inquiry. The inquiry teacher-mentors came to the instruction from a wide variety of prior backgrounds, from those whose main work was as teachers without experience in teaching through inquiry, through those who had recently retrained from hi-tech for teaching and have experience in work in technological projects, to those who have experience in leading research projects and instructing peers in the research. Accordingly, it is reasonable to expect great difference in the satisfaction of the students with the instruction.

2.5 Research Methods

The research study uses the mixed methods research methods, which combine elements of the qualitative and quantitative research approaches (Johnson, Onwuegbuzie, & Turner, 2007). There are a number of definitions of mixed methods research. The definition that suits this research study is the definition of Johnson, Onwuegbuzie, and Turner (2007, p. 120):

“Mixed methods research is the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study or set of related studies”.

Leech and Onwuegbuzie (2008) provide another definition. In general, mixed methods research represents research that involves collecting, analyzing, and interpreting quantitative and qualitative data in a single study or in a series of studies that investigate the same underlying phenomenon.

The rationale for the choice of this method is that the quantitative and qualitative combination provides a richer picture of the discussed phenomenon, an in-depth and in-breadth picture of the field. Through this combination, qualitative research methods can be used to increase the depth of the understanding of the findings that arises in the quantitative research method and the opposite is also true. Qualitative research complements the quantitative approach in that it attempts to understand the nature of the respondents' behavior and the way in which the respondents interpret their way of life (Sabar Ben-

Yehoshua, 1990). The research study is performed in the mixed methods research for the collection of information and validation of the findings to obtain as complete a picture as possible of the reality. Qualitative measures can improve quantitative measures when the concepts researched are not sufficiently clear to the researchers (Yoshikawa et al., 2008). Creswell et al. (2003) stated that the “purpose of the design is to use qualitative results to assist in explaining and interpreting the findings of the quantitative study” (p. 223).

Greene, Caracelli, and Graham (1989) and Greene and Caracelli (1997) developed five most important explanations (or most important goals) for the use of mixed methods:

1. Triangulation, which seeks convergence, approval, validation of data, and correspondence of results from different methods. Triangulation is the use of different methods to research the same phenomenon, so as to confirm and support the results in relation to the same phenomenon, to prevent mistakes of analysis and interpretation, to improve the internal and external validity, and to reinforce the confidence in the conclusions drawn about the phenomenon. According to Denzin (1978), triangulation is one of the main goals of the mixed methods research.
2. Complementarity searches for extension, improvement, illustration, and clarification of the results from one method with results from another method. Complementarity is the use of different methods to research different aspects of the same phenomenon, when one method helps in the clarification or improves, illustrates the result from another method, to further the depth of the interpretations given and to obtain a full picture of the phenomenon. The goal is not to confirm the results but to perceive a complementary facet of the reality.
3. Development seeks to use the results from one method to help develop or inform another method, in which the development is perceived in general so as to include sampling and measurement decisions. For instance, findings achieved in one method are used to develop another method.
4. Initiation seeks the discovery of paradox and contradiction of new perspectives of frameworks, reconstruction of questions or results from one method with questions or results from another method. Here too different aspects of the same phenomenon are researched. But here the goal is not to validate but to innovate, to create new questions or additional directions of research.

5. Expansion seeks to extend the range of the investigation through the use of different methods to different directions of inquiry. Expansion is the use of different methods to examine different phenomena that are a part of the broad range of the research study.

Beyond this, each one of the methods, qualitative and quantitative, has limitations and biases and therefore the use of more than one method may neutralize or overcome the biases of another method and thus contribute to the validation of the findings. Therefore, the mixed methods research study attempts to reduce the weaknesses and the problems related to each one of the methods, so as to improve the validity and reliability of the results and to enrich the understanding of the researched phenomenon. The recognition that research studies are not perfect and there are many factors of bias in all types of research studies encouraged organizations and researchers to combine between the methods in the same research so as to reduce the biases and enjoy the advantages of each one of the methods (Axinn & Pearce, 2006; Tashakkori & Teddlie, 2003).

Johnson and Turner (2003) maintain that it is wise to collect many groups of data through different research methods, so that the intervention or combination obtained has complementary strengths and weaknesses that do not overlap. Consequently, the mixed methods research approach helps improve the research quality (Johnson & Turner, 2003). Because the different research approaches have different strengths and different weaknesses, the mixed methods approach can bridge the gap between the qualitative and quantitative methods. One method can overcome its weakness through the strength of the other method (Ornwuegbuzie & Leech, 2005). For instance, the case of an experimental research may show good causality but it is possible that it is limited in realism because of the 'imprisonment' of the research laboratory. Conversely, an ethnographic research may not display especially good causality but it enables the researcher to look at the behavior as it occurs naturally in the field, and therefore it increases the realism. When the two methods are mixed, the causality is good, the realism is increased. As we saw in the example, all the research methods have structured limitations and through the integration of the methodologies in the research, the researcher can compensate for these limitations (Lonner, 2009).

In addition, according to Yoshikawa et al. (2008), the research methods must be suited to the research problem and research questions. The researcher must choose carefully research methods that will answer the research questions effectively (Johnson & Ongwuegbuzie, 2004). Indeed, the research method was set according to the questions of this research, which obligated qualitative and quantitative tools so as to respond to them. In this research study, there are areas in which there must be quantitative evaluation and the addition of a qualitative element enriches the view. In addition, in the research study there are areas in which there must be qualitative evaluation.

At the basis of the philosophical perception that unites the quantitative and qualitative approaches is the assumption that the human mind is dynamic, complex, and flexible, and should not be addressed as an animal that runs in a maze to obtain reinforcement or as a mystical creature, but exposed to influences of the past. To enter and understand the mind, the researchers are willing to receive the person's reports on the way in which he perceives himself, others, and the world. The human mind is similar to 'dynamic systems', with high difference between people. Therefore, there is guidance to take into consideration this difference and to combine the participants' outlook and not to address them as objects (Keenan, 2010). Since the person is composed of dynamic systems, it is necessary to represent it in every possible way and the integration of methods draws closer to the truth than each approach separately. Therefore, it is necessary to research through the integration of the quantitative and qualitative methodologies (Yoshikawa et al., 2008).

Some researchers tend to object to the integration of qualitative and quantitative approaches because they do not suit the paradigms and methods. There is a tendency to link between the positivist paradigms and the quantitative method and the interpretative and constructivist paradigms and the qualitative methods (Onwuegbuzie & Leech, 2005). The relationship between research methods is not unequivocal and is not sacred (Howe, 1992). Despite the objections to integrate between the quantitative approach and the qualitative approach in research (since the theoretical basis is different in both approaches and their fundamental assumptions are very different, for example, in objectivity, in sampling considerations, aspirations for generalization, prediction and finding laws as opposed to the special, spontaneous, and relative search) and despite additional difficulties such as the need for considerable use of different terms for the same method, the need for many

resources, the greater challenge in the synthesis of the findings, the greater complexity of performance in methodological terms, and the need for good mastery of both methods (qualitative/quantitative), the research study proposed here uses the mixed methods research that enables going in-depth in the research field, holistic understanding of the phenomena found in the research, enrichment of the learned body of knowledge, and validation of findings.

Both Creswell, Plano Clark, Gutmann, and Hanson (2003) and Creswell and Plano Clark (2011) says that there are main decisions in the choice of the mixed research strategy:

1. The determination of the order of performance of the collection of the data (are the data collected sequentially or concurrently?)
2. The determination of the priority/weight given to the quantitative method or the qualitative method in the research report (is there a weight equal to the two methods or preference to one of them – equal, not equivalent?) For instance, the researcher ascribes weight (at an equal status or dominant status) to one of the methods at the level of the collection of the data and in the dispersion of the results.
3. The determination of the place in the research process in which there will be integration between the qualitative and quantitative methods. (Is the integration between the methods in the stage of the collection of the data, in the stage of the analysis, or in the stage of the interpretation of the investigation?)

The combination of all these traits is expressed in the following definition. According to Creswell, Plano Clark, Gutmann, and Hanson (2003), a mixed method study “involves the collection or analysis of both quantitative and/or qualitative data in a single study in which the data are collected concurrently or sequentially, are given a priority, and involve the integration of the data at one or more stages in the process of research” (p. 212).

Creswell (2003) describes six models (designs) that can be used in mixed methods (that are not detailed here). According to the terminology of Creswell (2003), the research study proposed here uses for the most part the model of the concurrent strategy of triangulation – use of qualitative and quantitative methods in parallel (concurrently) and equally (See the following figure). The research study involves qualitative and quantitative research approaches in certain stages of the research process.

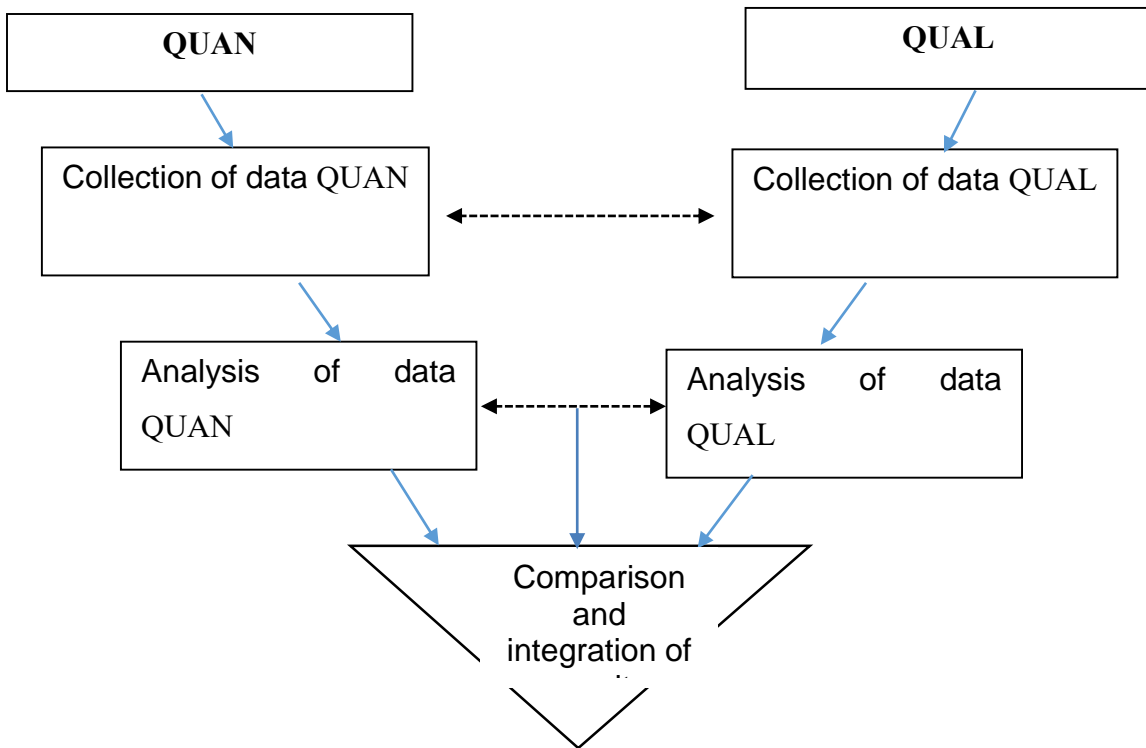


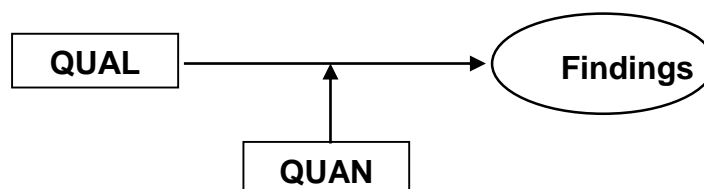
Figure 3: Concurrent Strategy of Triangulation- Research Design: Qualitative and Quantitative and Mixed Approaches (Creswell, 2003)

According to all the stages of the research study (the research objectives, data collection, analysis, and interpretation, conclusion), the research is a collection of qualitative and quantitative parts that have similar importance.



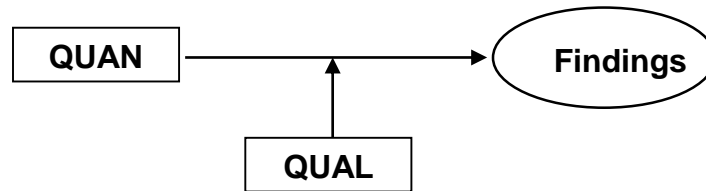
For instance, the research study conducted a survey and used a questionnaire composed of multiple closed-end and or quantitative items and a number of open or qualitative items.

In addition, at certain stages in the research study use was made of quantitative methods to add to the qualitative research.



For instance, the research study collected qualitative data but afterwards attempted to quantify the data.

In certain stages in the research study, use was made of qualitative methods to facilitate the explanation of the quantitative findings.



For instance, the research study conducted a quantitative examination and then an interview (qualitative) was held with some of the participants, so as to see their degree of confidence in their answers and to see whether they agreed with the results.

In the qualitative part of the research study, there will be a tendency towards inductivity, inference from a representative sample about the entire population. The research will attempt to examine specific phenomena/perceptions and to focus on a small amount of respondents and thus to create insight on the entire population that they represent (assuming that it is possible to generalize in some way about the entire population). The research study will draw conclusions about what is common between the data and the product obtained is a general idea/principle/rule. As a result of the induction, the research study will describe the laws in the world and will create new knowledge.

In the quantitative part of the research study, it is possible that there will be a tendency towards deduction, logical conclusion from a general fact, assumption, or conclusion to a specific case (from the general to the specific). The research study will attempt to conclude from all the respondents about the single person (although the number of the respondents is small relative to what is accepted in quantitative research). The validation in the research will be going back and forth, between deduction and induction.

2.6 Research Population

The research population consists of students who learn physics studies in high school (tenth to twelfth grades, fifteen to eighteen years old) and who participate in the 'Research Physics' Program in the Davidson Institute in the Weizmann Institute, Israel, in its second cycle, 2016-2019. The program operates in the afternoon outside of the school

walls. Since in every class there are only a few students who are interested in performing physics inquiry and were recommended by their teachers, it was necessary to collect small groups of students from a number of schools. Therefore, the research population includes students from five schools (regular schools which located near the Weizmann Institute area-half an hour drive). The students come to the Davidson Institute and become a **regional class**, 34 students, 12 girls and 22 boys, students with ability and interest to study physics phenomena.

These students chose to learn in the framework of 'Research Physics' in Davidson Institute and volunteered to participate in this research (with parental consent: see Appendix 2.5- letter of parental consent for their son / daughter to participate in this research). The research received approval from the Chief Scientist for Israel to follow up after this student and to ask students to take part in information gathering activities during the period of their participation in the program (filling out questionnaires, participating in semi-structured interviews, conducting observations held within the framework of the program, documenting of their answers and products, while using video or recordings).

2.7 Research Instruments

Before the research was carried out, there was the informed consent (oral) of the participants as well as the written consent of the participants and their parents (see the form in Appendix 2.5). The research study received the approval of the institutional ethics committee, by the Chief Scientist of Israel.

Before every performance of the research instrument, the students received an explanation about the nature of the research instruments (questionnaires, interviews, and observations). In addition, the students received an explanation of the research objectives, and the meaning of the different categories of research (e.g., the names of the various research components) and the actions in which they would be asked to do in each of the research instruments. All the respondents were told that the participation in the research is not mandatory and that the information will not go to their teacher-mentors or any other external factor but will remain confidential. The identifying details were eliminated from the database so as to avoid the identification of the participants.

The collection of the data will be undertaken through the use of a variety of research instruments and will include, as aforementioned, quantitative and qualitative instruments.

Quantitative and Qualitative Instruments in the Research

Questionnaires

Much thought has been invested in the questionnaire construction phase. The questions were constructed on the basis on a number of previous studies dealing with this the subject learning and teaching through inquiry (such as, Khishfe & Abd-El-Khalick, 2002; Sadeh & Zion, 2009). The questions were formulated so that it would be possible to obtain information from the respondents regarding the research questions (as much as possible). In order for the questionnaire to be reliable and valid it must be worded "correctly". Proper wording of the questionnaire increases the chance that the respondent will answer the questions in the way the researcher intended and honestly, hence also reduces the measurement errors in the questionnaire (Zemach & Beyt-Marom, 1986). Therefore, care was taken to formulate questions clearly and to avoid vague wording, and wording that includes several questions (so as not to confuse the respondent). In order for the questions in the questionnaire to be clear to the respondents, and to ensure better answers are received from the respondents, six students who did not participate in this research (of the same age) read the questions and marked questions that were not clear to them. Accordingly, the questions were corrected to questions that are clearly and simply formulated to them. The research took pains to phrase the questions as objectively, balanced, and impartially as possible, so that the findings would be reliable and valid.

In this research study, a number of questionnaires were deployed in different stages of the research. The questionnaires are composed of closed-ended and open-ended questions. In the closed-ended questions, according the accepted methods, choosing an answer from a number of possibilities and use of ranking scales (Ordinary questions- on the Likert scale). In the open-ended questions, the respondent expresses in writing his opinion on the researched topic according to predetermined questions.

As will be described in the following subchapter 2.8, In the quantitative analysis, use was made of the following statistical tests (Chi-square (χ^2) test and T-test). The

qualitative analysis is characterized by the following stages of analysis of the verbal data: sampling of the select verbal data from the students' answers according to the research objectives, development of a coding scheme, mapping and search for patterns (categories), interpretation of the patterns, and last presentation of the products of the analysis through verbal descriptions. The integration of quantitative analysis and qualitative analysis is expressed in the quantification of the qualitative analysis, or in other words, subjective quantitative coding of the qualitative data (Chi, 1997). (For a more extensive description of the paradigm of Chi for the analysis of qualitative data, see the next subchapter 2.8.)

Before the students filled out each questionnaire, the students received an explanation of the purpose of the research and its importance, and the meaning of the different categories of research (e.g., the names of the various research components and their meaning). It was made clear to them that the study will maintain confidentiality and they have the right to withdraw the study at any time. On each questionnaire it is written explicitly stating that the questionnaire is for research purposes only. The information provided in the questionnaires is confidential. Any future publication will not include identifying details of students.

Questionnaire 1. Preliminary questionnaire on the Research Physics Program (see appendix number 1.1). This questionnaire includes questions of two types, open-ended questions and close-ended questions. In the first part, open-ended questions were presented, in which the respondents will be asked to fill out personal information, write their expectations from the program, and share questions that engage them with regard to the program, concerns, and needs. In the second part, different factors that influence their decision to join the Research Physics program were presented. The respondent was asked to address every factor and to evaluate its influence on a Likert scale (of five levels: not at all, slightly, moderately, greatly, very greatly). In the third part, different ways were presented to perform an inquiry project in physics. The respondents were asked to note the degree of their identification with the entire way (on a scale of four levels: very greatly, rather greatly, rather slightly, very slightly) and to answer an open-ended question on the way they prefer to perform an inquiry project. In addition, different statements that address the student's experience in practical work in physics were presented. The respondent was asked to address every factor and to evaluate its influence on a Likert scale (of five levels: unfamiliar activity, slight experience, moderate experience, great experience, very great experience).

Questionnaire 2. Inquiry skills questionnaire (see appendix number 1.2). The students were asked to note the degree to which inquiry skills were expressed during the program on a scale of four levels from 0 (not at all) to 3 (very greatly). Last, the students were asked to choose from the list of skills mentioned two skills that were the hardest for them to perform and to explain their choice, and two skills that greatly developed in them during the inquiry work and to provide examples that show this development.

Questionnaire 3. Attitudes questionnaire (see appendix number 1.3). This questionnaire includes questions of two types. In the first part, open-ended questions are presented, in which the respondents need to note a number of differences between activities in the school laboratory and activities performed in the framework of the Research Physics program. In the second part, attitudes were presented towards the scientific researcher, towards scientific inquiry, and towards inquiry activities in the framework of research physics. The respondent was asked to address every variable and to evaluate it on a Likert Scale of five levels (from do not agree at all to agree greatly).

Questionnaire 4. Summative Questionnaire (see appendix number 1.4). This questionnaire includes open-ended questions and closed-ended questions on different topics. The students were presented with a series of statements that address their overall experience in the inquiry project. They needed to note the degree of agreement regarding every statement on a Likert scale. In the continuation of the questionnaire, another series of statements was presented addressing different possible components during the work on the inquiry project and the students had to answer the following questions. To what extent did you experience the coping with these components? To what extent did you experience difficulty in coping with these components? To what extent are you satisfied with the support you received in the coping with these components? Then the students needed to choose at least two components in which they noted that they experienced considerable difficulty and to describe the difficulty in these components and how they coped with the difficulties. In addition, they needed to choose from the series presented at least two components that they felt greatly developed in them during the program and to describe how they developed. In the continuation of the questionnaire, the students were asked to tell about the changes (at least two) they performed during the research work (for instance, change of topic, change of inquiry question, change in the system of the planning of the

experiment, change in the work program, conclusions, etc.) and to detail what caused the change and what they learned from it. Towards the end of the questionnaire, a series of possible goals for the program were presented. The students were asked to rank on a Likert scale the degree of contribution of the program to the development or improvement in each one of the goals. In addition, they were asked to note their degree of satisfaction regarding cooperation between the students and the teacher-mentors on a Likert scale and to detail what bothered them if they were not satisfied. At the end of the questionnaire, the students were asked to give a “tip”, to tell a lesson they learned to a student who is beginning this program, to note two-three strengths of the program that it is important to preserve, and to note two-three aspects of the program that should be changed, including an explanation.

Interviews with the Students Participating in the Research Physics Program

The interviews were open and semi-structured (see appendix number 1.5). In this type of interview, the phrasing of the main questions is undertaken ahead of time, but the continuum of their presentation is not determined beforehand and there is room during the interview to add questions according to the context, when sometimes the interviewee’s responses lead to spontaneous questions. The questions prepared ahead of time constituted in essence a formal interview, which sometimes is necessary to ensure the uniformity of the interview topics (Sabar Ben-Yehoshua, 2001; Shkedi, 2003). In Appendix 1.5 the main questions asked in the interviews are presented.

The goal of the interview is to achieve information on topics and aspects that it is impossible to achieve from the examination of questionnaires and inquiry works of students. For example, through the interviews it is possible to discern implicit (unexpressed) information and the researcher’s challenge is to make this knowledge overt knowledge (Shkedi, 2003).

Interviews were conducted with 11 students out of the 34 participants in the program, which took place after the end of the intermediate stage of the inquiry work (end of 11th grade). After about two years of getting to know the students from the observations, these students were chosen because I made a relationship of trust, openness with them, and there is a better chance of collaborating with them during the interviews and getting honest answers from them. In addition, about half (5 students) seemed to have great difficulty in research work and about half (6 students) had less difficulty, and it was important to interview students who coped differently. In addition, it was also important to address gender, of which, 6 boys and 5 girls.

The interviews were performed in oral, face-to-face conversations and through email, and some were recorded. In these interviews the students were asked about their inquiry project, the learning process they experienced in the performance of the inquiry project and in the program in general, the difficulties and the challenges they coped with during the performance of the inquiry project, and how they responded to them. In addition, the goal of the interviews was to obtain information for the evaluation of the dynamic inquiry skills the students acquired during their inquiry work and the knowledge that develops in them in all that pertains to the performance of their inquiry research, as well as information about the students' attitudes on the inquiry process, of the Research Physics learning environment. Particularly the role of the student and the teachers and the learning resources given to them in this environment, their attitudes on their ability to perform inquiry work, and their attitudes on the contribution of the program to their personal growth.

The disadvantage in the performance of an interview is the possible influence of the interviewer, in his reactions, on the interviewee's answers (Patton, 1990). The interview, in addition to being an instrument for the collection of information, is also a process in which a reality is created where the two partners in the interview may contribute to and be influenced by what is said to some extent or another (Woods, 1996).

In addition to possible influence on the very existence of the interview itself, there is the (natural) fear of some of the interviewees to express themselves freely in all that pertains to topics related to grades, the high school matriculation examinations, and the inquiry project, since they are directly and indirectly related to the interviewer. In parallel to the concerns, it is necessary to develop relations of trust with the interviewee (Shkedi, 2003) and non-formal encounters may increase the trust, with the goal of getting to know the students even before the interview (Sabar Ben-Yehoshua, 1999). Therefore, I joined most of the sessions of the program, I observed the students, I created relations of trust, I was interested in their inquiry project engagement, and I helped them as needed. In addition, to create a more intimate atmosphere while creating a system of trust, not all the interviews were recorded, as per the student's choice, despite the great importance of recording the interviews (Shkedi, 2003). Field records that included comments and insights were written down immediately during the interview at the end of the interview, so they would not be lost.

In all the interviews, the interviewees were assured confidentiality, so as to receive cooperation on their part. In addition, the respondents were asked for their permission to write down their words, sometimes to record them. They received an explanation why this is necessary for the research. An effort was made to conduct a neutral investigation, without judgment.

The research examines the influence of the program on the students during its implementation for three years and does not rely only on the interview of the students at the end of the intermediate stage. The examination of the influence of the program during its implementation requires detailed documentation and includes primarily lengthy observations.

Observation of the Activity of the Students in the Program Sessions in the Davidson Laboratory at the Weizmann Institute

The observations were held once every two weeks for the first year of the program (when the students were in the tenth grade) and once a week for the last two years of the program (the students were in the eleventh and twelfth grades). Every session lasted three hours.

Most of the observations in the research study are open-ended (unstructured) observations, or the observation and recording of events and behaviors in the researched environment, without planning ahead of time what is observed. The purpose is to document all the observed behaviors, as they occur in their natural environment. The advantage in this type of observation is the description of the behavior in a true situation. The disadvantage is that the observation does not explain why a certain behavior appears. In addition, a positive correlation between two phenomena does not necessarily indicate that one causes the other (Beyt-Marom & Ashkenazi, 2012).

Regarding the role of the researcher in this research study during the observations, in every observation the researcher decided the extent to which he is interested in being a partner in the occurrence. Some of the observations were ‘non-participative observations’, in which the researcher attempted to observe the respondents without coming into contact with them (in addition, generally the respondents forget that they are being observed). The researcher observed from the side, did not intervene in what is done, but serves as a

'camera' – attempted to be as much as possible 'the perfect observer'. Some of the observations were 'participative observations', in which the researcher participated actively during the encounters with the students, as an overt or cover observer. The level of participation was moderate and through extended stay (throughout all the three years of the students' studies). The goal is to accumulate experience and knowledge – to understand the researched experience, the language, and the culture from his perspective and in his natural environment. The difficulty in the performance of the observation of this type is that the researcher needs to observe and see what the respondents do and simultaneously must participate in what is done in the research environment. The challenges in this type of observation are the creation of an initial relationship with the respondents, a possible approach for the researcher to be involved in the respondents' life, the ability of objective observations, representation, and unique ethical issues (Beyt Marom & Ashkenazi, 2012). Some of the observations were overt observations. The respondents are aware of the fact that they are being observed. The disadvantage in the open observations is that they cause the respondents to behave differently, how they need to be perceived and not how they are in actuality (Beyt Marom & Ashkenazi, 2012). However, since the observer is alternately a participating observer, it appears that the respondents forget that they are being observed.

The research, during the observations, attempted to maintain observation and attention to the respondents in their natural environment, to understand how they interpret the world, and to write texts close to the respondents' experience. However, the research attempted to investigate through as naturalistic investigation as possible.

Observation of the Random 'Corridor Conversations' between the Students and Their Teacher-Mentor

Throughout the research I observed these conversations that were held primarily before and at the end of the activities, in the recesses. The purpose of these conversations is to receive from interrogees a general impression of the activities in the program about their general feeling at the meeting. It is also possible to receive messages / insights from the interaction between the students and the teacher-mentor at an informal

Documentation of Students' Products Used in the Program

The students' products for three years of the program include performance tasks during the sessions, writing reports, presentations, learning materials they have achieved, and a portfolio (research diary) which is in the model of the program (the model also includes the activities of the program).

Personal Conversations with the Program's Development and leadership team, Teacher-Mentors, Laboratory Assistants Supporting the Program, and Physics Teachers whose Students Participate in the Program. These conversations were performed face-to-face, on Skype, and by emails throughout the research, mainly about the structure of intervention.

2.8 Description of the Data Analysis

As described in the previous chapter and as can be seen from the following table 2.1, in this research study use was made of questionnaires, interviews, observations, and documenting of the students' inquiry projects. The research relied on the collection of quantitative and qualitative data.

In the quantitative analysis, use was made of the following statistical tests:

1. Chi-square (χ^2) test was used to examine whether there is statistical relationship (dependence) between two variables (when there is a significant difference $p < .05$). This research study examines the relationship between different dates in the program (preparation stage, intermediate stage, final stage of the Inquiry Project) for the researched phenomenon according to the research questions (the students' perception of the experience, the challenge, and the development in the different stages in the program). Also in cases where quantitative analysis was integrated with qualitative analysis there was use of this statistical test. Using this test, developmental research is done, which describes the changes in the researched phenomenon in the different stages of the three-year "Research Physics" program.
2. t-test for paired samples was used to examine the difference between a pair of measurements (at different times) of the same variable on the same group of subjects. According to the research questions (students' attitudes on the inquiry process and the Research Physics learning environment, mainly on the roles of the

teacher and the student in the inquiry work and the learning resources that are given to them in the program). Significant difference ($p < .05$) between the measurements can indicate the contribution of the experiment to the change in student's position. The statements were measured in the Likert scale – an ordinal scale, and there is an implicit assumption that this scale is at least an interval scale, since the gap between 1 and 2 is equal to the gap between 2 and 3 and onward (Birenboim, 1997). In which the ranking was: high values denote a higher place in the measured trait than the low values, for example, if student's consent is measured on a scale of 1 to 5, when 1 is "do not agree" at all and 5 is "definitely agree".

In the qualitative analysis, the students' answers (to the open-ended questions) were sorted into different categories, in order to quantify the data. Data analysis was principally based upon Chi's paradigm (Chi, 1997) for the analysis of qualitative data, basically, it's a kind of analysis that quantifies qualitative codings. The main steps in the analysis were:

1. First, reducing or sampling the verbal data. After collecting verbal data and transcribing them, they are ready for coding. This study has a large amount of data, and only a sample of them was selected to encode.
2. Segmenting the reduced or sampled data. Repeated reading of student answers and grouping similar answers - several sentences relating to a single idea. Segmenting the data into units of pre-determined categories - once the categories (set or subset) of the verbal data to be coded are decided, then it is necessary to segment the verbal data and identify the unit of analysis
3. Generating bottom-up categories - categories stemming from students' ideas are generated.
4. Comparison of bottom-up categories to theory-driven categories, searching for theory-driven categories in the data. Then one has to develop new codes, modify them, or refine them.

5. Finally, refinement and synthesis of bottom-up and theory-driven categories to a unified coding scheme, and defining the categories ¹³with respect to the research questions.
6. Sorting students' answers into the defined categories.
 - The categories in the first inquiry question: description of the aspects of the development of the students and description of the experience and challenge they faced in the performance of the different inquiry components during the “Research Physics” Program in the fifteen components of research: choosing the topic, phrasing the questions/goals, locating information sources, planning an experiment, performing an experiment, using technological aids and a computerized laboratory, data processing, drawing conclusions, written reporting on the inquiry, oral reporting on the inquiry, building content knowledge, building a theoretical model, self-regulation, teamwork with the partner, teamwork with peers in the broader group.
 - The categories in the second inquiry question: The students’ perception of inquiry process and the “Research Physics” learning environment (in particular the role of the students and the teachers and the learning resources) in the aspects of management of the inquiry work (in the context of responsibility, independence, and initiative, planning and organizing the inquiry work, coping with the dynamism of the inquiry and with situations of uncertainty), building knowledge content (in the context of the student’s active learning and independent learning), teamwork with the project partner and with peers in the broader group, identification with the world of the scientific researcher.

Research Instruments relate to the Research Questions

The following table shows how the research instruments relate to the research questions – detailed the research instruments used to answer each one of the research questions.

¹³ Other experts (Prof. Edit Yerushalmi and Prof. Stanisław Dylak) examined the placement of categories on about a quarter of student responses. In addition, the issues whose categorization was debated were discussed. If there were disagreements, they were again discussed, and sometimes the category definition changed, until full agreement was reached.

Table 3: Research Instruments relate to the Research Questions (Sigron, M)

Research Questions / Research Instruments	Quantitative / Qualitative instruments	Distribution times of the research instrument	1A Students' perception of <u>their experience and challenge</u> in various inquiry components	1B Students' perception of <u>their development</u> in various inquiry components	1C Students' perception of <u>their development relate to their perception of the experience and challenge</u> in various inquiry components	2 students' perception of <u>the learning environment in the "research physics" program</u> (roles of students and teachers and learning resources)
Questionnaire 1: A preliminary questionnaire	quantitative	1.2017	✓			
Questionnaire 2: Inquiry skills questionnaire	quantitative and qualitative	5.2017	✓	✓	✓	
Questionnaire 3: Attitudes questionnaire	quantitative and qualitative	First: 2.2018 Second: 1.2019				✓
Questionnaire 4: Summative Questionnaire	quantitative and qualitative	First: 4.2018 Second: 5.2019	✓	✓	✓	✓
Interviews	qualitative	5-7.2018				✓
Observation of the students' activities	qualitative	Once every two weeks in 2017 and once a week in 2018-2019			✓	

Times of the Distribution of the Research Instruments and the Data Collection

In the research, the collection of the data was performed using questionnaires and interviews. Some of these questionnaires were distributed twice during the program, to examine the development of the students in the various research components and their perceptions with exposure to the program aspects.

In addition, the data were collected through the documenting of the learning materials and products of the students and through observations of the students throughout all their studies in the program (from the tenth grade to the twelfth grade), in the meetings in which they carried out inquiry activity in the laboratory of the Davidson Institute, the Weizmann Institute, Israel.

The dates of the distribution of the questionnaires are according to the exposure to the different inquiry practices in in the various activities of program framework (See table 4), according to the characterization table below.

Table 4: Times of the Distribution of the Research Instruments and the Data Collection (Sigron, M)

Collection Instrument / Time division	Preliminary questionnaire	Inquiry skills questionnaire	Attitudes questionnaire	Summative Questionnaire	Interview	Attitudes questionnaire (repeat)	Summative Questionnaire (repeat)
According to the intervention structure (See table 1.2- details of the activities)	At the beginning of the program (In activity 10th grade -1)	Before the submission of the mini-project report ¹⁸ , before the students' presentation (After activity 10th grade -5)	After the submission of the first intent document ¹⁷ (In the middle of activity 11th grade -3)	Before the submission of the intermediate report ¹⁶ , after the students' presentation (After the end of activity 11th grade -3)	After the students' presentation on the project (After the end of activity 11th grade -3)	After the submission of the second intent document ¹⁵ (After the end of activity 12th grade -1)	Before the submission of the summative report ¹⁴ , after the students' presentation (Towards the end of activity 12th grade -2)
Date	1.2017	5.2017	2.2018	4.2018	5-7.2018	1.2019	5.2019
Grade	In 10th grade, at the beginning	In the second half of the 10th grade	In the first half of the 11th grade	In the second half of the 11th grade	At the end of the 11th grade	In the first half of the 12th grade	In the second half of the 12th grade
The stages of the program	Preparation Stage		Intermediate Stage			Final Stage	

¹⁴ see appendix 2.4

¹⁵ see appendix 2.3

¹⁶ see appendix 2.3

¹⁷ see appendix 2.3

¹⁸ see appendix 2.4

3. Findings and Conclusions for the First Research Question

This chapter presents findings and conclusions for the first research question on the students' perception of their learning along the inquiry activities at various stages of the “Research Physics” program:

1) How did students’ perception of their development relate to their perception of the experience and challenge in performing various inquiry components¹⁹ along the stages²⁰ of the 'Research Physics' Program?²¹

In particular:

A) Students’ perception of their **experience and challenge** in each stage of the program:

- To what extent did students experience each of the inquiry components?
- To what extent did students find these components to be challenging for them?
- What are the challenges that students identify they have faced and what means did they use to cope with them?

B) Students’ perception of their **development** in each stage of the program:

- To what extent did students develop in each of the inquiry components?
- What aspects of the inquiry components do student believe that they have developed and what are the causes for this development?

C) **Students' development, following experience and challenge** in each stage of the program:

- How did the extent of the students’ development in the various inquiry components relate to the extent of experience and challenge in these components?
- How do the experiences, challenges, and development, as perceived by the students, correspond to the observed experiences, challenges and development?

¹⁹ In 15 components of inquiry: Choosing a topic, Locating data sources, Phrasing goals/questions, Planning an experiment, Performing an experiment, Using technological aids and a computerized laboratory, Data processing, Building a theoretical model, Drawing conclusions, Written reporting on the inquiry, Oral reporting on the inquiry, Building content knowledge, Self-regulation, Teamwork with the partner, Teamwork with peers in the broader group

²⁰ Stages of the program: a preparation stage for the inquiry project, an intermediate stage and a final stage of inquiry work (see chapter 1.2.4.3- Intervention Structure of the "Research Physics" Program

²¹ Quantitative & Qualitative instruments: Preliminary questionnaire (N=33), Inquiry skills questionnaire (N=27), Summative questionnaire (first N=33, second N=34), Observation of the students' activities

Accordingly, the chapter of the research findings is divided into three main subchapters:

1. Findings for part A of the first research question – the students’ perception of the **experience** and **challenge** in the performance of the different inquiry components.
2. Findings for part B of the first research question – the students’ perception of **their development** in the different inquiry components.
3. Findings for part C of the first research question – the **relationship between the development, experience, and challenges** the students experienced in the performance of the different inquiry components.

The categories in the first inquiry question: description of the aspects of the development of the students and description of the experiences and challenges they faced in the performance of the different inquiry components during the “Research Physics” Program in the fifteen components of inquiry: choosing the topic, phrasing the questions/goals, locating information sources, planning an experiment, performing an experiment, using technological aids and a computerized laboratory, data processing, drawing conclusions, written reporting on the inquiry, oral reporting on the inquiry, building content knowledge, building a theoretical model, self-regulation, teamwork with the partner, teamwork with peers in the broader group.

The components are slightly different between the first stage (the stage of preparation) and the other two stages, the second stage (the intermediate stage) and the third stage (the final stage of the inquiry project) in the very structure of the activity. In the preparation stage, the students engage in relatively short activities that have the ‘taste’ of inquiry, the students try inquiry activities that take a week to a month (that emphasize every time a specific practice / research instrument), while in the second and the third stages the students are already engaging in the annual project, a long-term inquiry project that lasts about a year and a half.

In the two stages, the second stage and the third stage, the students experienced all the inquiry components of the first stage: phrasing questions/goals, planning an experiment, performing an experiment, data processing, drawing conclusions, written reporting on the inquiry, and oral reporting on the inquiry. However, some of the components were extended because of the significant time that was dedicated to them in

the annual project relative to the mini-project in the preparation stage, and components for the second stage and the third stage were added (which were required in the large annual project but not in the preparation stage):

1. To the component of “phrasing inquiry questions/goals” was added the “choosing the inquiry topic”, which was allotted significant time in the annual project.
2. The component of “locating information sources” instead of the component of “positing a hypothesis” was added. In the different stages the students first posed a hypothesis, but did not dedicate time to theoretically establish the hypothesis – they were not asked to explain their hypothesis or to propose a possible explanation of their hypothesis from existing scientific knowledge or from their previous knowledge, but the students engaged more in the search for relevant knowledge on the phenomenon.
3. To the component of the “performing an experiment” was added the component of “using technological aids and a computerized laboratory”, to which was dedicated considerable time in the annual project.
4. Theoretical components were added – the component of “building content knowledge” and the component of “building a theoretical model”, so as to reflect the broad role in the annual project of theory-based modeling, in addition to empirical modeling. In many of the projects the students built a quantitative theory-based model for the performance of a comparison of the theoretical prediction and the experimental measurement. Generally, the building of a theoretical model was performed after the building of the experimental model and the knowledge required for this was considerable.
5. Meta-cognitive and socio-cultural components were added. “Self-regulation”, “team work” (with the partner on the project and with peers in the broader group), and “identifying with the world of scientific inquiry”. The annual project obligated more complex coping with self-management and with management of working in a team and allowed the students greater identification with an authentic research process.

3.1 Findings for Part A of the First Research Question: The Students' Perception of the Experience and Challenge in the Performance of the Different Inquiry Components

This chapter presents findings²² that answer the research question on the students' perception of their **experience and challenge** in each stage of the program:

- To what extent did students experience each of the inquiry components?
- To what extent did students find these components to be challenging for them?
- What are the challenges that students identify they have faced and what means did they use to cope with them?

This chapter describes a quantitative analysis of the distribution of the students' responses on the experience and challenge they experienced in performance different components in the inquiry work and qualitative analysis of the main points of their responses. When in the first three subchapters the findings are described in three different points in time in the program: the stage of preparation, the intermediate stage, and the final stage of the inquiry project. The last subchapter presents the comparisons between the different stages, a summary and an overlook (quantitative analysis) of the students' perception of the experience and challenge in the performance of different inquiry components throughout the inquiry work, and a summary (qualitative analysis) of the main challenges that arose from the students' reports in every inquiry component in the different stages of the inquiry work.

²² From quantitative & qualitative instruments: Preliminary questionnaire (N=33), Inquiry skills questionnaire (N=27), Summative questionnaire (first N=33, second N=34)

3.1.1 Stage 1: Preparation Stage of the Inquiry Project – Experience and Challenge in the Performance of the Inquiry Components (Self-Reporting Questionnaire before the Submission of the “Mini-Project” Report, 10th Grade)

This section presents a quantitative analysis of the students’ reports of the **experience and challenge** in the performance of the different inquiry components in the preparation e stage of the inquiry project and qualitative analysis of the difficulties and challenges they experienced in each component in this stage, from the Inquiry Skills Questionnaire (see appendix number 1.2). The questionnaire was held before the submission of the report on the “mini-project”, in the second half of the tenth grade (May 2017), N=27. There is no close teacher-mentor for each team of students but rather accompaniment and support of two program teacher-mentors for all the teams.

3.1.1.1 Quantitative Analysis – Degree of Experience and Challenge in the Performance of the Inquiry Components (Stag 1 – 10th Grade)

The following figures represent the students’ reporting on the considerable experience / difficulty in the performance of the different inquiry components in the second half of the tenth grade- before the submission of the “mini-project” report (from the the Inquiry Skills Questionnaire). In the questionnaire, the students (N=27) were asked to choose at least two inquiry components that in their opinion they experienced considerably during the inquiry work.

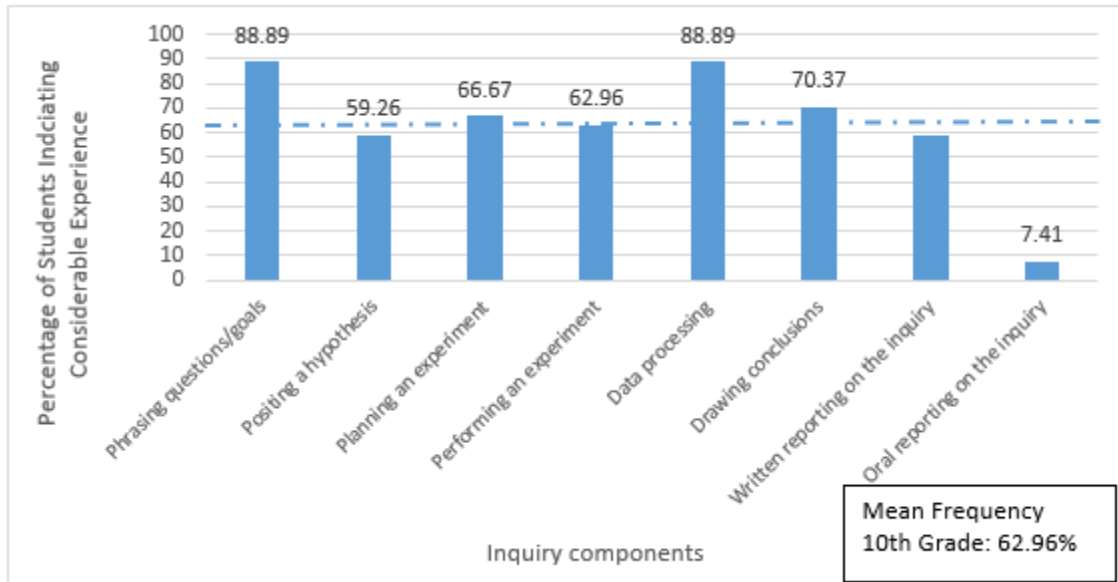


Figure 4: Report of Students on **Considerable Experience** in the Performance of the Different Inquiry Components in the **Preparation Stage** for the Inquiry Project (10th Grade - N=27)

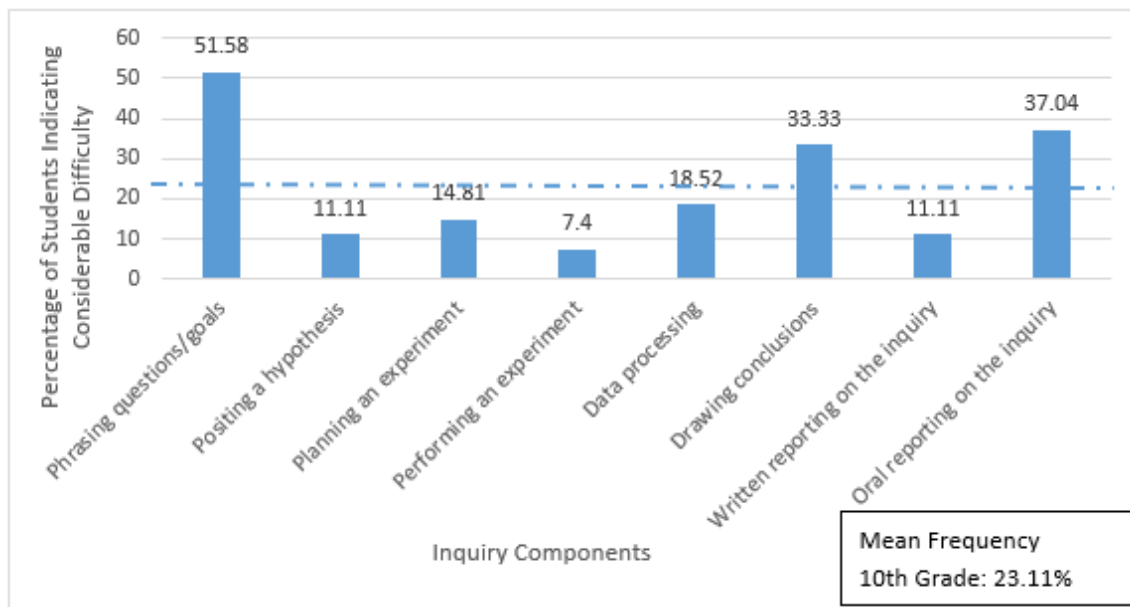


Figure 5: Report of Students on **Considerable Difficulty** in the Performance of the Different Inquiry Components in the **Preparation Stage** for the Inquiry Project (10th Grade, N=27)

It is possible to see from the above bar charts that:

- The inquiry components in which many students (above the mean frequency) reported that they experienced a considerable degree of difficulty are: phrasing questions/goals, drawing conclusions, and oral reporting on the inquiry. There was an especially high percentage in the component of phrasing questions/goals. In the components of phrasing questions/goals and drawing conclusions many students (above the mean frequency) reported considerable experience, while few students (under the mean frequency) report this in the component of oral reporting on the inquiry.
- The inquiry components in which few students (under the mean frequency) reported that they experienced a considerable degree of difficulty are: positing a hypothesis, planning an experiment, performing an experiment, data processing, and written reporting on the inquiry. An especially low percentage was noted in the inquiry components of positing a hypothesis, performing an experiment, and written reporting on the inquiry. In the components of planning an experiment, performing an experiment, and data processing, many students (above the mean frequency) reported considerable experience while few students (under the mean frequency) report this in the components of positing a hypothesis and written reporting on the inquiry.

3.1.1.2 Qualitative Analysis – Detailed Description of the Students’ Challenges in Each Inquiry Component (Stag 1 – 10th Grade)

The following section presents a qualitative analysis of the students’ reports about the difficulties and challenges they experienced (Appendix 3.1.1 is shown examples of students' citations) in the performance of the different inquiry components during work on the “mini project” in the second half of the tenth grade (from the Inquiry Skills Questionnaire), N=27. In this part, the description of the difficulties in the different inquiry components that arose from the students’ responses to questions: “Choose from the list of these skills (or others) two skills that are hardest to perform in your opinion. Explain your choice.”

Inquiry Component: Phrasing Questions/Goals

About one-half of the students (51.85%) reported that they experienced considerable difficulty with the performance of the component of phrasing goals/questions. About one-third of them explained what the difficulty with this component was.

The students describe difficulties in the performance of a component in the component of the phrasing goals/questions in the following aspects (Appendix 3.1.1 presents examples of student citations that illustrate these aspects):

1. General difficulty with conveying the thought to the formation of the question/goal.
2. Difficulty with phrasing the inquiry question, mainly out of awareness of the importance in the inquiry process.
3. Difficulty with choosing the inquiry question, so that it will be interesting and in essence will lead the direction of the investigation.
4. Difficulty with locating and identifying the factors that influence the phenomenon, especially when there is no prior knowledge on the phenomenon.
5. Difficulty with deploying creative thinking in the asking of the questions.

Inquiry Component: Positing a Hypothesis

About one-tenth of the students (11.11%) reported that they experienced great difficulty with the performance of the component of positing a hypothesis.

The students describe difficulties with the performance of a component in the component of positing a hypothesis in the following aspect (Appendix 3.1.1 presents examples of student citations that illustrate this aspect):

1. Difficulty with finding the balance between free thought and reliance on a previous theory/ previous knowledge.

Inquiry component: Planning an Experiment

14.81% of the students reported that they experienced considerable difficulty in performing the component of planning an experiment. Not one student described the difficulties in this component.

Inquiry component: Performing an Experiment

Very few students, less than one-tenth of the students (7.4%), reported that they experienced considerable difficulty in the performance of the experiment. The students described difficulties in the performance of a component from the component performing

an experiment in the following aspect (Appendix 3.1.1 presents examples of student citations that illustrate this aspect):

1. Coping with the existence of random mistakes in the performance of an experiment, like human errors.

Inquiry Component: Data Processing

About one-fifth (18.52%) of the students reported that they experienced considerable difficulty in the performance of the component of data processing. The students describe difficulties in the performance of a component of the component of data processing in the following aspects (Appendix 3.1.1 presents examples of student citations that illustrate this aspect):

1. Difficulty with building graphs in a computerized environment.

Inquiry Component: Drawing Conclusions

One-third of the students (33.33%) reported that they experienced considerable difficulty with the performance of the component of drawing conclusions. The students describe difficulties in the performance of a component in the component of drawing conclusions in the following aspects (Appendix 3.1.1 presents examples of student citations that illustrate these aspects):

1. Difficulty with finding a relationship between two factors.
2. Difficulty with implementing high level thinking strategies (like understanding, analysis, and synthesis) to reach conclusions.
3. Difficulty with comparing between theory and the experiment findings.

Inquiry component: Written Reporting on the Inquiry

About one-tenth of the students (11.11%) reported that they experienced considerable difficulty in the performance of the component of written reporting on the inquiry. The students describe difficulties with the performance of a component from the component of written reporting on the inquiry in the following aspects (Appendix 3.1.1 presents examples of student citations that illustrate this aspect):

1. General difficulty in verbal phrasing, which includes also transition from graphical representation to verbal representation.

Inquiry Component: Oral Reporting of the Inquiry

One of the components in which it was prominent that there were difficulties with performance is oral reporting on the inquiry. More than one-third of the students (37.04%) reported that they experienced considerable difficulty in the performance of the component of the oral reporting of the inquiry in front of teacher-mentors and colleagues. The students describe difficulties in the performance of a component in the component of oral reporting of the inquiry in the following aspects (Appendix 3.1.1 presents examples of student citations that illustrate these aspects):

1. General difficulty with conveying the thought into oral expression.
2. Difficulty during the time of the presentation with the mastery of the accumulated knowledge on the inquiry.
3. The coping with stress and the embarrassment that exists when standing in front of an audience.

3.1.2 Stage 2: Intermediate Stage of the Inquiry Project – Experience and Challenge in the Performance of the Inquiry Components (Self-Reporting Questionnaire before the Submission of the Intermediate Report, 11th Grade)

This section presents a quantitative analysis of the students' reports on the experience and challenge in the different inquiry components in the intermediate stage of the inquiry project and a qualitative analysis of the difficulties and challenges experienced in each component in this stage, from the Summative Questionnaire (see appendix number 1.4). The questionnaire was carried out before the submission of the intermediate report of the project, in the second half of the tenth grade, after the students' presentation on the project (April 30, 2018), N=33. when there is a teacher-mentor for each research team.

3.1.2.1 Quantitative Analysis – Degree of Experience and Challenge in the Performance of the Inquiry Components (Stag 2 – 11th Grade)

The following figures represent the students' reporting on the considerable experience / difficulty in performance of the different inquiry components in the second half of the eleventh grade- after the students' presentation of the inquiry project and before the submission of the intermediate report (from the Summative Questionnaire). In the

questionnaire, the students (N=33) were asked to choose inquiry components (at least two components) in which in their opinion they had experience / difficulty to a considerable extent during the inquiry work.

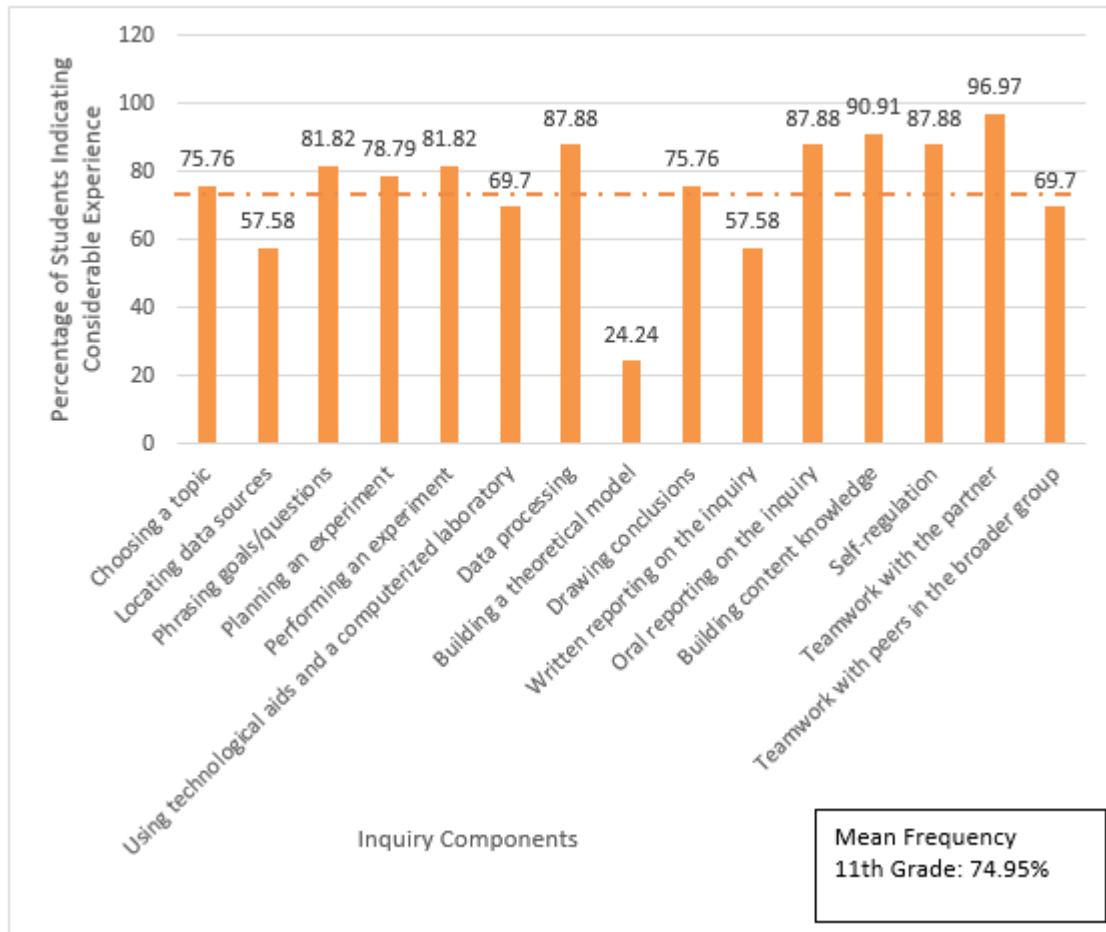


Figure 6: Report of the Students on the **Considerable Experience** in the Performance of the Different Inquiry Components in the **Intermediate Stage** of the Inquiry Work (11th Grade, N=33)

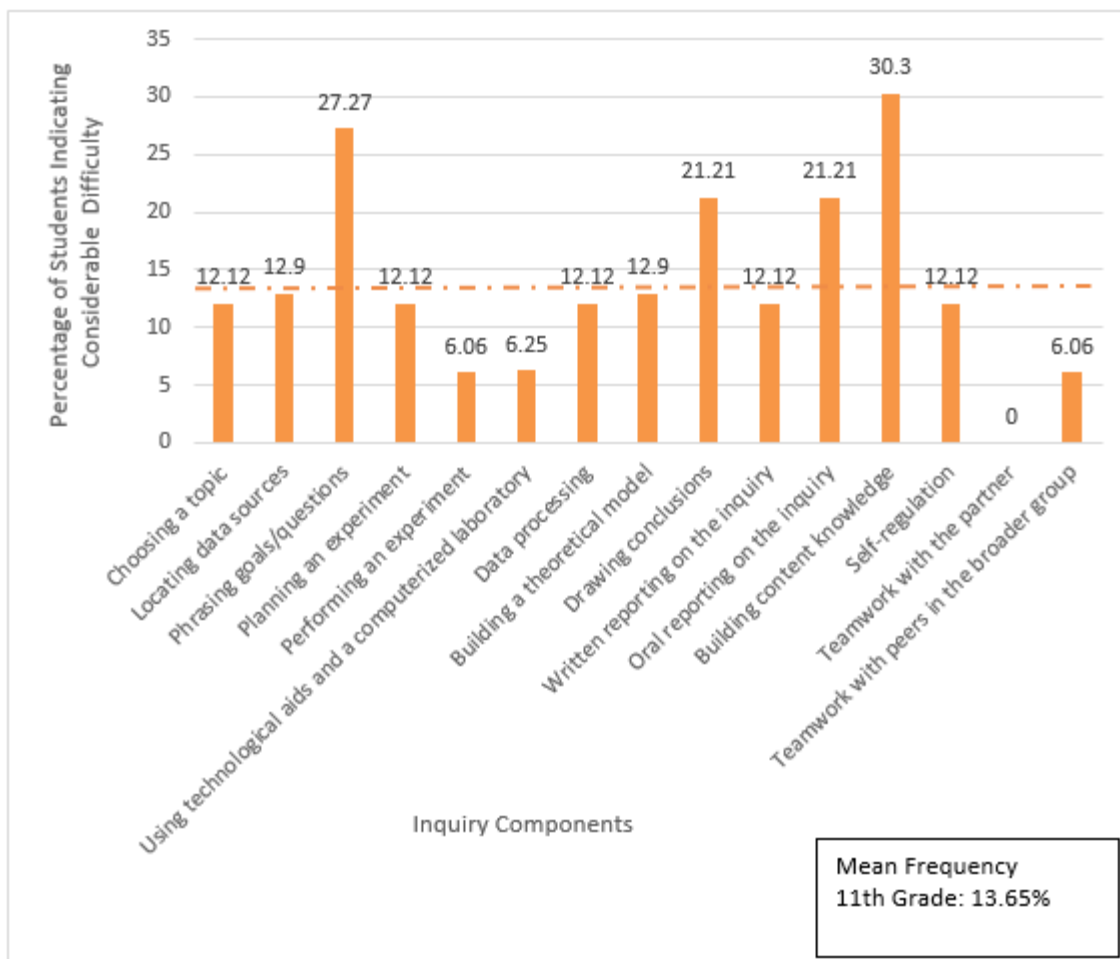


Figure 7: Report of the Students on the **Considerable Difficulty** in the Performance of the Different Inquiry Components in the **Intermediate Stage** of the Inquiry Work (11th Grade, N=33)

It is possible to see from the above bar charts that:

- The inquiry components in which many students (above the mean frequency) reported that they experienced considerable difficulty are: phrasing questions/goals, drawing conclusions, oral report of the research, and building content knowledge. An especially high percentage indicated the inquiry components of building content knowledge and phrasing questions/goals, when in each of these four components many students (above the mean frequency) reported considerable experience.

- The inquiry components in which few students (below the mean frequency) reported that they experienced considerable difficulty are choosing the topic, locating information sources, planning an experiment, performing an experiment, using technological aids and a computerized laboratory, data processing, building a theoretical model, written reporting on the inquiry, self-regulation, teamwork with the partner, and teamwork with peers in the broader group. An especially low percentage indicated the inquiry components of planning an experiment, using technological aids and a computerized laboratory, teamwork with the partner, and teamwork with the peers. Many students (above the mean frequency) reported considerable experience in the components of choosing a topic, planning an experiment, performing an experiment, data processing, self-regulation, and teamwork with the partner (especially high percentage), while in the components of locating information sources, using technological aids and a computerized laboratory, building a theoretical model, written reporting on the inquiry, and teamwork with peers in the broader group few students (below the mean frequency) reported considerable experience. An especially low percentage indicated the component of building a theoretical model.

3.1.2.2 Qualitative Analysis – Detailed Description of the Students’ Challenges in Each Inquiry Component (Stag 2 – 11th Grade)

The following section presents a qualitative analysis of the students’ reports about the difficulties and challenges they experienced (Appendix 3.1.2 is shown examples of student citations) in the performance of the different inquiry components before the submission of the intermediate report of the project in the second half of the eleventh grade (from the Summative Questionnaire), N=33. In this part, the description of the difficulties in the different inquiry components that arose from the students’ responses to question: “Choose at least two components in which you noted that you experienced considerable difficulty. Describe what was the difficulty in these components, how did you cope with these difficulties?” and question: “Regarding your satisfaction about the cooperation between the students and the teacher-mentors, if you are not satisfied, please describe what bothered you” and in question: “Note two-three aspects of the program that should be changed and explain”.

Inquiry Component: Choosing an Inquiry Topic

About one-tenth of the students (12.12%) reported that they experienced considerable difficulty with the performance of the component of choosing a topic. The students describe difficulties in the performance of choosing an inquiry research topic in the following aspects (Appendix 3.1.2 presents examples of student citations that illustrate these aspects):

1. Difficulty with choosing a topic that is not familiar and is new for the students.
2. Deliberations on choosing a topic according to the degree of the challenge, interest, and complexity of the topics.
3. The number of possibilities of choosing inquiry topics is limited and the choice is from a database and is not free.

The students describe suggestions ways of coping with these difficulties:

1. To broaden the database of research topics in the program.

Inquiry Component: Phrasing Questions/Goals

One of the prominent components since they were difficult to perform is the component of the phrasing of goals/questions. Slightly more than one-quarter of the students (27.27%) reported that they experienced considerable difficulty in the component of the phrasing of goals/questions. We note that in this questionnaire fewer students chose this component as a difficult component to perform than in the previous questionnaire but still a not insignificant number of students were identified as having considerable difficulties in the performance of this component.

The students describe difficulties in the performance of the component of phrasing questions/goals in the following aspects (Appendix 3.1.2 presents examples of student citations that illustrate these aspects):

1. Difficulty with the focusing of the inquiry question and prevention of dispersion to the different directions of investigation.
2. Difficulty with bringing up an inquiry question when there is no previous knowledge on the topic.

The students describe suggestions ways of coping with these difficulties:

1. To return to the original / first inquiry question and focus on it.

2. To choose one inquiry question and focus on the direction in which there are important / interesting findings.
3. To get to know the topic extensively.

Inquiry component: Locating Information Sources

A little more than one-tenth of the students (12.09%) reported that they experienced considerable difficulty in the component of the locating of information sources. The students describe difficulties in the performance of the locating of information sources in the following aspects (Appendix 3.1.2 presents examples of student citations that illustrate these aspects):

1. Finding a low number of sources relevant to the researched phenomenon.
2. Lack of knowledge and experience in finding evaluated, quality, and high level information sources.
3. Difficulty with the multiplicity of information sources when the phenomenon is composed of sub-phenomena and many components.

The students describe suggestions ways of coping with these difficulties:

1. To ask for help from the teacher-mentors in the search of information sources on the topic.

Inquiry Component: Planning an Experiment

About one-tenth of the students (12.12%) reported that they experienced considerable difficulty with the component of the planning of an experiment. It should be noted that in this questionnaire the students brought up descriptions of difficulties in this component, what was not in the previous questionnaire. It is reasonable to assume that the students are more mature in the inquiry process, which is expressed in the ability to give better explained and more detailed feedback. In addition, it is possible to see that the students use scientific language and concepts of research of this component, like “isolating variables”.

The students describe difficulties in the performance of the component of planning an experiment in the following aspects (Appendix 3.1.2 presents examples of student citations that illustrate these aspects):

1. Difficulty with performing isolation of variables in the process of planning the experiment.

2. Coping with the dynamism of planning the experiment to increase the effectiveness and improve the experiment system.

The students describe suggestions ways of coping with these difficulties:

1. To seek advice from the teacher-mentor in the planning of the experiment that will enable the isolation of variables.
2. To group thinking – brainstorming with the partner in the project for ideas.
3. To find creative ways to plan the building of the system and to isolate the variables.

Inquiry Component: Performing an Experiment

Very few of the students (6.06%) reported that they experienced great difficulty in the component of performing an experiment. The students describe difficulties in the component of performing an experiment in the following aspects (Appendix 3.1.2 presents examples of student citations that illustrate these aspects):

1. Difficulty with independently finding the equipment required for an experiment in the laboratory.
2. Difficulty with building the experiment system independently, which derives from the lack of familiarity with the topic and with the system components.
3. Difficulty with operating parts of the system independently.

The students describe suggestions ways of coping with these difficulties:

1. To obtain help from the teacher-mentor and the laboratory assistants in the building of the system and in the implementation of parts of the system.

Inquiry Component: Using Technological Aids and a Computerized Laboratory

Less than one-tenth (6.25%) of the students reported that they experienced great difficulty in the component of using technological tools and a computerized laboratory in the time of the experiment performance. The students describe difficulties in the component of using technological aids and a computerized laboratory in the following aspects (Appendix 3.1.2 presents examples of student citations that illustrate these aspects):

1. Difficulty operating different technological instruments and in a computerized laboratory (such as sensors, computerized programs), which derives from the lack of knowledge/experience in the use of these instruments.
2. Coping with lack of accuracy and sensitivity of the technological measurement devices.

The students describe suggestions ways of coping with these difficulties:

1. To obtain help from the teacher-mentor and the laboratory assistants, explanations, and illustration of the operation and use of technological instruments and computerized programs.
2. To be determined and to perform trial and error with these instruments.
3. To maintain laboratory equipment and purchase more sophisticated equipment to build systems of experimentation that will allow more accurate measurement.

Inquiry Component: Data Processing

About one-tenth of the students (12.12%) reported that they experienced considerable difficulty in the component of data processing. Only one student bothered to describe a number of difficulties related to this component. The students describe difficulties in the component of data processing in the following aspects (Appendix 3.1.2 presents examples of student citations that illustrate these aspects):

1. Difficulty with classifying data relevant to the inquiry question.
2. Difficulty with independently transitioning from raw data to complicated data.

The students describe suggestions ways of coping with these difficulties:

1. To use critical thinking in the classifying of the data
2. Teamwork with the partner in the project

Inquiry Component: Drawing Conclusions

About one-fifth of the students (21.21%) reported that they experienced considerable difficulty in the component of drawing conclusions. The students describe difficulties in the component of drawing conclusions in the following aspects (Appendix 3.1.2 presents examples of student citations that illustrate these aspects):

1. Difficulty when the results are not commensurate with the theory and it is necessary to find an explanation of this gap in the conclusions
2. Difficulty when a theory relevant to the research, upon which it will be possible to base the conclusions, is not found.
3. Difficulty when the theory is very complicated mathematically (in the students' opinion) to reach conclusions.

The students describe suggestions ways of coping with these difficulties:

1. To think jointly with the team members.

2. To find creative ways, such as the use of calculated modeling to overcome the complicated mathematical solution from the students' perspective and to create a formula that connects between the variables.
3. To receive help from the teacher-mentor in finding the relationship and the conclusions.

Inquiry Component: Written Reporting on the Inquiry

About one-tenth of the students (12.12%) reported considerable difficulty with the written reporting on the inquiry. The students describe difficulties in the component of written reporting on the inquiry in the following aspects (Appendix 3.1.2 presents examples of student citations that illustrate these aspects):

1. Difficulty with summarizing the main points in the writing of the presentation.
2. Lack of time and resourcefulness for documenting the research work.

The students describe suggestions ways of coping with these difficulties:

1. Teamwork and support of the teacher-mentor.
2. To bring to the students' awareness the importance of documenting the research work and encouraging them to do so.

Inquiry Component: Oral Reporting on the Inquiry

About one-fifth of the students (21.21%) reported that they experienced considerable difficulty in the component of oral reporting on the inquiry. The students describe difficulties in the component of oral reporting on the inquiry in the following aspects (Appendix 3.1.2 presents examples of student citations that illustrate these aspects):

1. Fear and even anxiety about standing and presenting in front of an audience.
2. Difficulty with keeping to the allotted time for the presentation of the inquiry.
3. Fear that the oral presentation may harm the image of the quality of the project work.

The students describe suggestions ways of coping with these difficulties:

1. To practice and train at home on the inquiry presentation before peers and family members.
2. To plan ahead of time the content of the presentation and the manner of the presentation.
3. To carry out more intermediate presentations and peer assessment during the inquiry work to improve the presentation and to perform follow-up and supervision.

Inquiry Component: Building Content Knowledge

The component that was most prominent in this questionnaire as a component that is hard to perform is the component of the building of content knowledge. About one-third of the students (30.30%) reported that they experienced considerable difficulty in building the content. The students describe difficulties in the component of “building content knowledge” in the following aspects (Appendix 3.1.2 presents examples of student citations that illustrate these aspects):

1. Difficulty with learning and understanding in-depth the contents required for the project, especially when there is no prior knowledge about the inquiry topics and the theoretical material is new for them.
2. Difficulty with independent learning of the contents relevant to the inquiry.
3. Coping with the complexity of the theoretical material and its high level.

The students describe suggestions ways of coping with these difficulties:

1. To locate relevant sources for the researched topic.
2. To ask the help of the teacher-mentors to obtain explanations for things that are not understood or are complex.

Inquiry Component: Building a Theoretical Model

14.81% of the students reported that they experienced considerable difficulty in the component of building a theoretical model. The students describe difficulties with the component of building a theoretical model in the following aspect (Appendix 3.1.2 presents examples of student citations that illustrate this aspect):

1. Difficulty with building a theoretical model, primarily through computational modeling, both in the correct writing of the physical principles related to the researched phenomenon and in the correct writing of the programming language.

The students describe suggestions ways of coping with these difficulties:

1. To obtain help from the teacher-mentors and laboratory assistants who understand computational modeling.
2. To learn from observation of computational models made in the past.
3. To raise the awareness of the students of the importance and effectiveness of computational modeling through which it is possible to build a good theoretical model.
4. To seek advice of experts on the topic to improve the theoretical model.

Inquiry Component: Self-Regulation

A little more than one-tenth of the students (12.12%) reported that they experienced considerable difficulty in the component of self-regulation in the context of the management of the inquiry work that includes planning and organization of the inquiry work, meeting the time schedule, and dealing with situations of uncertainty during the inquiry work. Despite the small percentage of this component relative to the rest of the components, in the qualitative analysis more than one-third of the students experienced certain difficulty (not great) and described different difficulties in the coping with the components related to the self-regulation. About 20% of the students who reported that they experienced a certain difficulty in self-regulation in the context of the management of inquiry work described a difficulty related to the practice of planning and organization of the inquiry work, about one half of them described a difficulty with meeting a time schedule, and more than one-third addressed the difficulties that arise from the coping with situations of uncertainty during the inquiry process.

The students describe difficulties in the component of self-regulation in the context of the management of the inquiry work in the following aspects (Appendix 3.1.2 presents examples of student citations that illustrate these aspects):

Difficulties with planning and organizing the inquiry work:

1. Difficulty with the organization of the inquiry work, because of the large and extensive scope that is required to carry out an inquiry project in this program, both in terms of the learning materials of the inquiry topic and in the many performances of inquiry carried out in the project.

Difficulties with meeting the time schedule:

2. Difficulty with meeting the time schedule because of the great load in this period of the students' lives from the additional commitments beyond the inquiry work of the program and because of all sorts of problems that appeared during the work.

Difficulties with coping in situations of uncertainty:

3. Difficulty with performance of an intelligent decision in the choice of directions of investigation of the project during the inquiry work.
4. Reaching the fulfillment of the investigation in the middle of the process and lack of knowledge on the continuation of the direction of the investigation.

5. Reaching the situation of lack of satisfaction with the inquiry performed and/or lack of confidence in the quality of the inquiry.

The students describe suggestions ways of coping with planning and organizing of the inquiry work:

1. To be aware of the importance and carrying out of orderly documenting of the inquiry in a “research journal”, in which all the research processes are documented (description of experiments and outcomes, films, photos, processing of results, experiment, and conclusions, learning material relevant to the inquiry, etc.).
2. To plan the work ahead of time and implementing methodical think from the beginning of the inquiry.

The students describe suggestions ways of coping with meeting of the time schedule:

1. To correctly manage the time, determine the more correct priorities, and make more time available for the work at home.
2. Teamwork that includes the division of labor between the project partners.
3. To introduce self-motivation to promote the inquiry.
4. To choose a simpler and less complex research question to meet the times.
5. To change the hours of activity of the program to a more comfortable and appropriate to the school system.
6. To lengthen the duration of time of every session or the beginning of the project at an earlier stage in the program to complete and reach a full and in-depth inquiry.

The students describe suggestions ways of coping with situations of uncertainty:

1. To make intelligent and joint decisions with the partner.
2. To be determined and to persist in the investigation.
3. To reinforce and support the project partner.

Inquiry Component: Teamwork with the Project Partner

Not one student reported that they experienced considerable difficulty.

Inquiry component: Teamwork with the Peers in the Broader Group

Very few students (6.6%) noted that they had considerable difficulty in the teamwork with the rest of the peers who are participating in the program. The students did not describe difficulties with teamwork between the student and all the other peers in the broader group.

3.1.3 Stage 3: Final Stage of the Inquiry Project – Experience and Challenge in the Performance of the Inquiry Components (Self-Reporting Questionnaire before the Submission of the Summative Report, 12th Grade)

This section presents a quantitative analysis of the students' reports on the experience and the challenge in the performance of the different inquiry components in the final stage of the inquiry project and a qualitative analysis of the difficulties and challenges experienced in every component in this stage, from the Summative Questionnaire (see appendix number 1.4). The questionnaire was distributed before the submission of the summative report of the project, in the second half of the twelfth grade, after the students' presentation of the project (May 2019), N=34, when there is a teacher-mentor for every research team.

3.1.3.1 Quantitative Analysis – Degree of Experience and Challenge in the Performance of the Inquiry Components (Stag 3 – 12th Grade)

The following figures represent the students' reporting on considerable experience / difficulty in the performance of the different inquiry components in the second half of the twelfth grade- after the students' presentation of the inquiry project and before the submission of the summative report (from the Summative Questionnaire (repeat)). In the questionnaire, the students (N=34) were asked to choose at least two inquiry components in which in their opinion they experienced considerable experience / difficulty during the inquiry work.

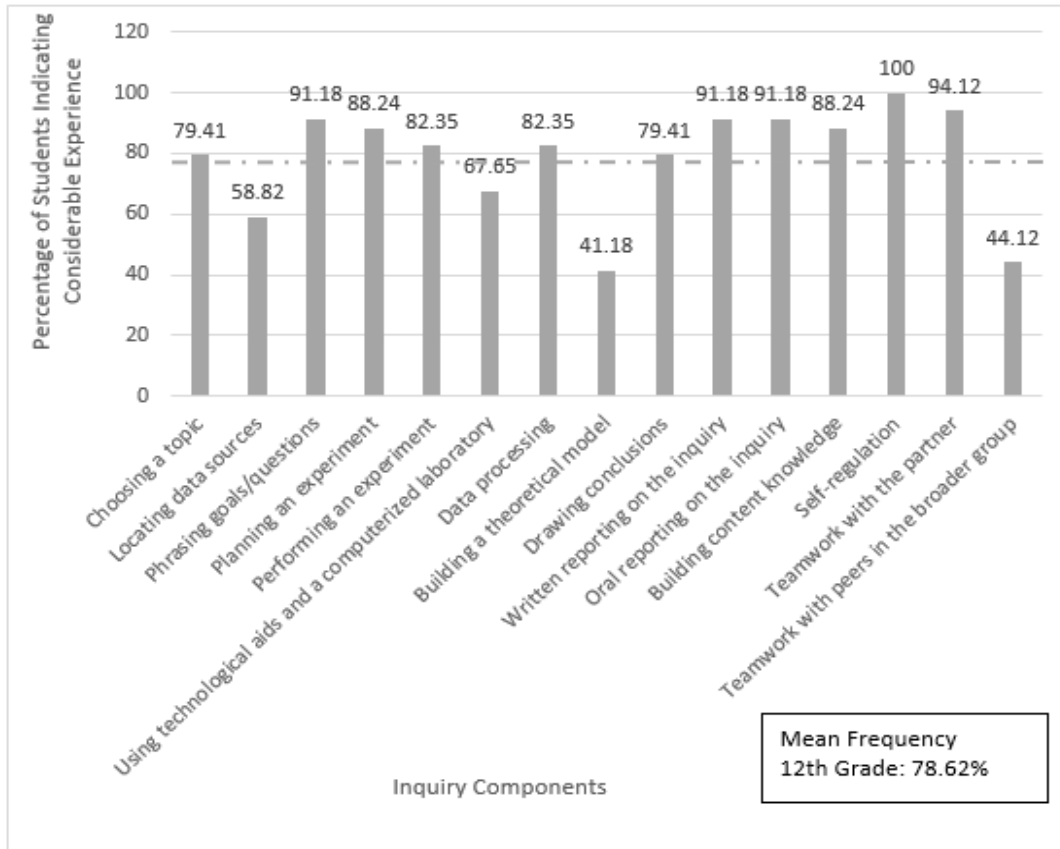


Figure 8: Report of Students on **Considerable Experience** in the Performance of the Different Inquiry Components in the **Final Stage** of the Inquiry Project (12th Grade, N=34)

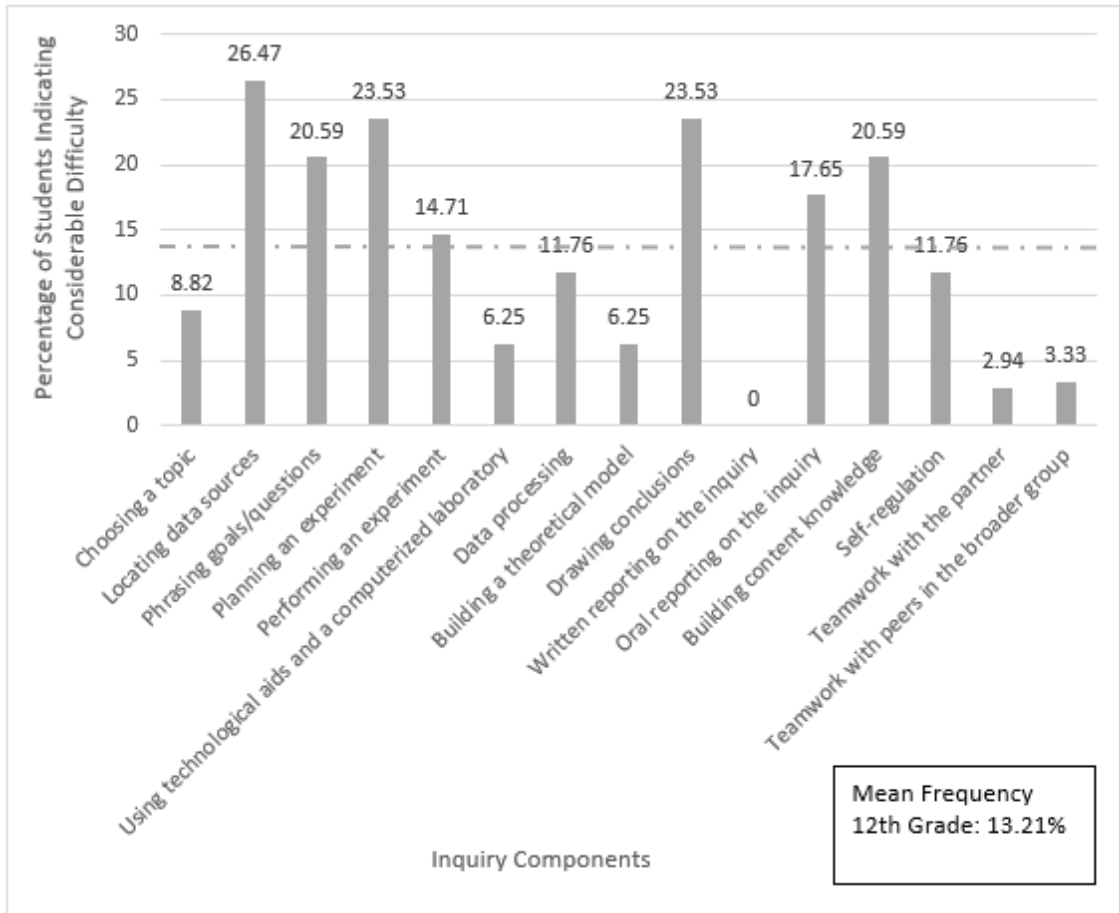


Figure 9: Report of Students on Considerable **Difficulty** in the Performance of the Different Inquiry Components in the **Final Stage** of the Inquiry Project (12th Grade - N=34)

It is possible to see from the above bar charts that:

- The inquiry components in which many students (above the mean frequency) reported that they experienced considerable difficulty are locating information sources, phrasing questions/goals, planning an experiment, performing an experiment, drawing conclusions, building content knowledge, and oral reporting on the inquiry. There is an especially high percentage in the inquiry components of locating information sources, planning an experiment, and drawing conclusions, when in each of these components, with the exception of the component of locating information sources, many students (above the mean frequency) reported considerable experience, while in the component of locating information sources few students (below the mean frequency) reported this.

- The inquiry components in which few students (below the mean frequency) reported that they experienced considerable difficulty are choosing a topic, using technological aids and a computerized laboratory, data processing, building a theoretical model, oral reporting on the inquiry, self-regulation, teamwork with the partner, and teamwork with the peers in the broader group. An especially low percentage was noted in the inquiry components written reporting on the inquiry, teamwork with the partner and teamwork with peers, when many students (above the mean frequency) reported considerable experience in the components of choosing a topic, data processing, written reporting on the inquiry, self-regulation (an especially high percentage), and teamwork with the partner. In the components of using technological aids and a computerized laboratory, building a theoretical model, and teamwork with peers in the broader group, few students (below the mean frequency) reported this. There was an especially low percentage in the components of building a theoretical model and teamwork with peers in the broader group.

3.1.3.2 Qualitative Analysis – Detailed Description of the Students’ Challenges in Each Inquiry Component (Stag 3 – 12th Grade)

The following sections present a qualitative analysis of the students’ reports about the difficulties and challenges they experienced (Appendix 3.1.3 is shown examples of student citations) in the performance of the different inquiry components before the submission of a summative report of the project, in the second half of the 12th grade (from the Summative Questionnaire), N=34. This part presents the description of the difficulties in the different inquiry components, which arose from the students’ responses to the question: “They chose at least two components that you noted that they experienced considerable difficulty about them. Describe what was the difficulty in these components, how they coped with these difficulties?” and the question: “Regarding their satisfaction about the cooperation between students and teacher-mentors, if you are not satisfied, then please describe what bothered you” and in question: “Note two-three aspects of the program that should be changed and explain”.

Inquiry Component: Choosing an Inquiry Topic

Less than one-tenth of the students (8.82%) reported that they experienced great difficulty in the performance of the choosing a topic, and few students described difficulties in this component.

The students describe difficulties in the component choosing the topic in the following aspects (Appendix 3.1.3 presents examples of student citations that illustrate these aspects):

1. Difficulty with the focusing on the inquiry topic and avoidance of dispersion to other directions of investigation.
2. It is impossible to change the topic in an advanced stage of the research despite the great difficulty of the students in understanding the topic.

The students describe suggestions ways of coping with these difficulties:

1. To receive help and direction from the teacher-mentor.

Inquiry Component: Phrasing Questions/Goals

About one-fifth of the students (20.59%) reported that they experienced considerable difficulty in the component of the phrasing of goals/questions. The students describe difficulties in the component of phrasing questions/goals in the following aspects (Appendix 3.1.3 presents examples of student citations that illustrate these aspects):

1. Difficulty with choosing an inquiry question, which will be interesting for all the team members.
2. Difficulty with focusing the inquiry question.

The students describe suggestions ways of coping with these difficulties:

1. To use thinking and reason in the choice of the inquiry question, so that it will be focused, investigable, and interesting for the researcher.
2. To receive help and direction from the teacher-mentors.

Inquiry Component: Locating Information Sources

The component that was prominent in this questionnaire as a component that is hard to perform relative to the other components is the locating of information sources. Slightly more than one-quarter of the students (26.47%) reported that they experienced considerable difficulty in the component of locating information sources relevant to the inquiry topic. The students describe difficulties in the component of locating information sources in the

following aspect (Appendix 3.1.3 presents examples of student citations that illustrate this aspect):

1. Finding a low number of sources relevant to the inquiry topic, primarily when the researched phenomenon is not widespread and because of their little experience in this component.

The students describe suggestions ways of coping with these difficulties:

1. To add experiences in the component of locating information sources already in the first year of the program, in the stage of the preparation and not only in the work on the project.

Inquiry Component: Planning an Experiment

One of the prominent components since they were difficult to perform in the students' eyes is the component of the planning of an experiment. Slightly less than one-quarter of the students (23.53%) reported that they experienced considerable difficulty in this component. The students describe difficulties in the component of planning an experiment in the following aspects (Appendix 3.1.3 presents examples of student citations that illustrate these aspects):

1. Difficulty with planning a system that will answer the inquiry question, especially when the existing system does not allow isolation and measurement of the desired variables.
2. Coping dynamically with the planning of the experiment system, which changes according to the inquiry needs.
3. Difficulty with planning an experiment that will bring up quantitative data and not only qualitative data.

The students describe suggestions ways of coping with these difficulties:

1. To persevere, be determined, and implement thinking filled with planning to reach a good and improved system to the greatest possible extent.
2. To change the direction of investigation because of the requirement for the planning of a quantitative experiment and not only a qualitative one.
3. To recognize and accept the dynamism of the component of planning an experiment to create a more in-depth and in-breadth investigation and to create a line linking between the first experiments and the new direction of investigation.

Inquiry Component: Performing an Experiment

About one-seventh of the students (14.71%) reported that they experienced considerable difficulty in the component of performing an experiment. The students describe difficulties in the component of performing an experiment in the following aspects (Appendix 3.1.3 presents examples of student citations that illustrate these aspects):

1. Difficulty with building an experiment system that will allow accurate measurements (because of factors of error in the experiment, limitation of the experiment system, and lack of equipment and means in the laboratory).
2. Coping with the dynamism of the experiment performance in the inquiry process, which is expressed in the performance of repeated experiments and in the improvement of the experiment system.

The students describe suggestions ways of coping with these difficulties:

1. To minimize the factors of error in the experiment system and to attempt to isolate the variables as much as possible.
2. To take data from existing articles on an identical experiment to analyze more accurate data.
3. To build computational modeling for the phenomenon.
4. To improve the laboratory, like acquiring more reliable and sophisticated measurement tools, for performing more accurate measurements.
5. To persevere and be determined.
6. To think creatively.

Inquiry component: Using Technological Aids and a Computerized Laboratory

Very few students (6.25%) experienced considerable difficulty in the component of using technological aids and a computerized laboratory and also these students did not describe difficulties in this component.

Inquiry component: Data Processing

A little more than one-tenth of the students (11.76%) reported that they experienced considerable difficulty in the component of data processing. Very few students described difficulties in this component. The students describe difficulties in the component of data processing in the following aspect (Appendix 3.1.3 presents examples of student citations that illustrate this aspect):

1. Difficulty with collecting and analyzing the data, because of the large scope of data and especially when the action is monotonous it sometimes led to frustration.

The students describe suggestions ways of coping with these difficulties:

1. Considerable investment and considerable time.
2. Correct planning of time.

Inquiry Component: Drawing Conclusions

One of the components in which it was prominent that there were difficulties in performance in the students' opinion is the component of drawing conclusions. Nearly one-quarter of the students (23.53%) reported that they experienced considerable difficulty in this component. However, very few students describe the difficulties with which they coped in the performance of this component. The students describe difficulties in the component of drawing conclusions in the following aspect (Appendix 3.1.3 presents examples of student citations that illustrate this aspect):

1. Difficulty with the comparison between the theory and findings of the experiment and especially when there is a large gap between them.

The students describe suggestions ways of coping with these difficulties:

1. Critical thinking.
2. Greater depth of investigation to attain reliable conclusions.

Inquiry Component: Written Reporting on the Inquiry

Although not one student reported experiencing considerable difficulty in the component of written reporting on the inquiry, nearly two-thirds of the students experienced certain difficulty and described different difficulties related to this component.

The students describe difficulties in the component of written reporting on the inquiry in the following aspects (Appendix 3.1.3 presents examples of student citations that illustrate these aspects):

1. Difficulty with persevering in the continuous and consistent documenting of the process of the investigation.
2. Difficulty with verbal phrasing of the description of the work components like description of the experiments, description of the conclusions, and description of the reflection.

3. Difficulty with the organization of the summative work, ordering the work components in logical continuum that is interesting to the reader.
4. Difficulty with the differentiation between the major and minor points and performing decisions in the choice of things that will be presented in the presentation.

The students describe suggestions ways of coping with these difficulties:

1. To write an inquiry journal, which includes the entire process of inquiry and its products.
2. To reconstruct and recollect things that happened in the investigation but not always with success.
3. To classify inquiry products and differentiate the main points, primarily in the stage of the writing of the presentation.

Inquiry Component: Oral Reporting on the Inquiry

A little more than one-sixth of the students (17.65%) reported that they experienced considerable difficulty in the component of oral reporting on the inquiry. The students describe difficulties in the component of oral reporting on the inquiry in the following aspect (Appendix 3.1.3 presents examples of student citations that illustrate these aspects):

1. Coping with the fear and stress that exist in standing in front of an audience.

The students describe suggestions ways of coping with these difficulties:

1. To perform rehearsals of the presentation before the family and peers.
2. To accumulate experience in presentations during the program.
3. To master the content knowledge and the inquiry process towards the presentation so as to increase the self-confidence and self-efficacy of students in presenting before an audience.
4. To frequently present to the audience during the program to improve the related skills.

Inquiry Component: Building Content Knowledge

One of the components in which it was prominent that there were difficulties with performance in the students' opinion is the component of building content knowledge. About one-fifth of the students (20.59%) reported that they experienced considerable difficulty in this component. The students describe difficulties in the component of building content knowledge in the following aspects (Appendix 3.1.3 presents examples of student citations that illustrate these aspects):

1. Coping with the learning of completely new theoretical material.
2. Difficulty with in-depth understanding of the researched phenomenon, primarily learning of physical contents at a high level.
3. Difficulty with independent learning of the theory relevant to the inquiry.
4. Difficulty with learning and understanding the theoretical background because of the lack of finding relevant information sources to the investigated phenomenon.
5. Difficulty with good mastery of the mathematical tools at a high level to advance in the learning of the theoretical material and to reach greater depth of understanding.

The students describe suggestions ways of coping with these difficulties:

1. To obtain help and support from the teacher-mentors.
2. To mutually fertilize in learning with the partner.
3. To turn to experts in the researched field.
4. To invest in learning and in practice of the theoretical material.
5. To promote awareness and understanding of students that to advance in inquiry it is necessary to adopt an independent learning style

Inquiry component: Building a Theoretical Model

Very few students (6.25%) reported that they experienced considerable difficulty in the component of the building of a theoretical model. In addition, very few students described difficulties in this component.

The students describe difficulties in the component of building a theoretical model in the following aspect (Appendix 3.1.3 presents examples of student citations that illustrate this aspect):

1. Difficulty with building a theoretical model primarily in computational modeling, both because of the need to master the theoretical background and the need for high mathematical knowledge relevant to the investigation and because of the mastery of the new programming language.

The students describe suggestions ways of coping with these difficulties:

1. To receive help and support from the teacher-mentors and academic coordinators.

Inquiry Component: Self-Regulation

A little more than one-tenth of the students (11.76%) reported that they experienced considerable difficulty in the component of self-regulation in the context of the management of the inquiry work that includes planning and organizing the inquiry work, meeting the time schedule, and dealing with situations of uncertainty during the inquiry work. Despite the small percentage relative to the rest of the components, in the qualitative analysis of this component nearly two-thirds of the students experienced a certain degree of difficulty (not great) and described different difficulties with coping with component related to self-regulation. About one-third of them emphasized that the difficulty is planning and organization the inquiry work, about one-half described difficulty with meeting the time schedule, and about one-quarter addressed difficulties that arise from coping with situations of uncertainty during the inquiry process.

The students describe difficulties with the component of self-regulation in the context of the management of the inquiry work in the following aspects (Appendix 3.1.3 presents examples of student citations that illustrate these aspects):

Difficulties planning and organizing the inquiry work:

1. Difficulty with taking personal considerable responsibility of the student for the planning and organizing of the inquiry work that requires discipline and self-management.
2. Difficulty with functioning of the logistics of the management and organization of the inquiry required in the afternoon hours, after the day of studies in the school.

Difficulties with meeting the time schedule:

3. Difficulty with meeting the considerable pressure and time schedule both because of other commitments outside of the program, especially for students in the 12th grade who are approaching the preparation tests and high school matriculation examinations, and because of the load of tasks to complete the inquiry project in the research physics program.

Difficulties in coping in situations of lack of certainty:

4. Reaching a “dead end” and lack of knowledge how to advance in the inquiry, which led sometimes to considerable frustration.

5. Reaching a situation of dispersion in the inquiry work and/or lack of organization and there is no guideline throughout the entire work.
6. Coping with many frustrations and feeling of powerlessness when reaching situations of uncertainty.

The students describe suggestions ways of coping with planning and organizing the inquiry work:

1. To plan a work program for following sessions.

The students describe suggestions ways of coping with meeting of the time schedule:

1. To invest considerable time in the work of the project also in the late hours of the light.
2. To plan a correct time schedule.
3. To strengthen student's feeling of commitment to the project partner, which created in the student the motivation to meet the time schedule, so that he will not be an inhibiting factor that may harm the partner.

The students describe suggestions ways of coping with situations of uncertainty:

1. To perform follow-up after the progress of the inquiry work of the entire project (the entire research team) so as to ascertain that the chosen topic is investigable, that the student has the tools to research it, and to locate the students who are 'stuck' and to help them in earlier stages.
2. To seek help and support from the teacher-mentors and academic counselors.
3. To advance awareness of the existence of situations of uncertainty and powerlessness in the inquiry process and therefore not to be deterred and not to despair when encountering these situations and it is possible to overcome them because of perseverance in the inquiry.
4. To focus on the researched topic and investigation in-depth of the topic and prevention of dispersion and superficial investigation of many topics.
5. To hold a lesson for students with the goal of teaching ways of coping with situations of uncertainty, management of inquiry work, and meeting a time schedule.

Inquiry Component: Teamwork with the Project Partner

Very few students (2.94%) reported that they experienced great difficulty in the teamwork with their partner in the project. However, in the qualitative analysis more students described that they experienced difficulty to a certain degree (not great).

The students describe difficulties in the component of teamwork with the project partner in the following aspects (Appendix 3.1.3 presents examples of student citations that illustrate these aspects):

1. Difficulty with the coordination of times between the team members.
2. Difficulty with planning the division of the inquiry work and the roles in the team, so that it is fair and accepted by the team members.

The students describe suggestions ways of coping with these difficulties:

1. To coordinate work times between the team members.
2. To have a fair division of labor accepted by the team members.
3. To undertake preparation activities for works in a team for a term longer than the first year of the program.

Inquiry Component: Teamwork with Peers in the Broader Group

Very few students (3.33%) reported that they experienced considerable difficulty in teamwork with the peers in the broader group who are participating in the program. The students described lack of satisfaction in the teamwork with the peers in the broader group.

Lack of satisfaction of the students with teamwork with the peers in the broader group (Appendix 3.1.3 presents examples of student citations that illustrate these aspects):

1. With the social interaction with the rest of the peers in the broader group in the program.
2. With the sparse activities that include peer assessment.

The students describe suggestions ways of coping with these difficulties:

1. To increase the social interaction with the rest of the peers and even to undertake activities for group formation to create more opportunities for social interaction.
2. To increase the number of activities that include the assessment of the peers in the program, especially when the peers are the same age and therefore their critical review is received in a social manner and less as criticism than that of the teacher-mentors.

3.1.4 Comparison between the Stages (Preparation, Intermediate, and Final) of the Inquiry Project – Experience and Challenge in the Performance of the Inquiry Components

This section presents a comparison of the experience and challenge that the students experienced in the inquiry components between the different stages in the program. In each stage, the students were asked to choose at least two inquiry components in which, in their opinion, they experienced considerable experience / difficulty during the inquiry work. In the first part, we will address only the inquiry components that were shared by all the questionnaires at three different points in time: the stage of preparation, the intermediate stage, and the final stage of the inquiry work, and that constitute a main part of the inquiry process. In the second part, we will extend to additional inquiry components, which were examined only in the last two stages of the inquiry work (the consideration on the addition of inquiry components in the last two stages is explained at the start of this chapter). In the last subchapter, we will present a summary and overall picture of the students' perception of the experience and challenge in the performance of the inquiry components throughout the entire inquiry work.

3.1.4.1 Experience and Challenge of Students in the Performance of the Inquiry Components Examined in Three Stages

3.1.4.1.1 Comparison between Stage 1 (Preparation Stage) and Stage 2 (Intermediate Stage) – Experience and Challenge of Students in the Performance of the Inquiry Components

The following figure represents the students' reporting on the **considerable experience** in the performance of the different inquiry components – comparison between the preparation stage of the inquiry project (in the second half of the tenth grade, N=27, before the submission of the mini-project report, from the Inquiry Skills Questionnaire) and the intermediate stage (in the second half of the eleventh grade, N=33, before the submission of the project intermediate report, from the Summative Questionnaire).

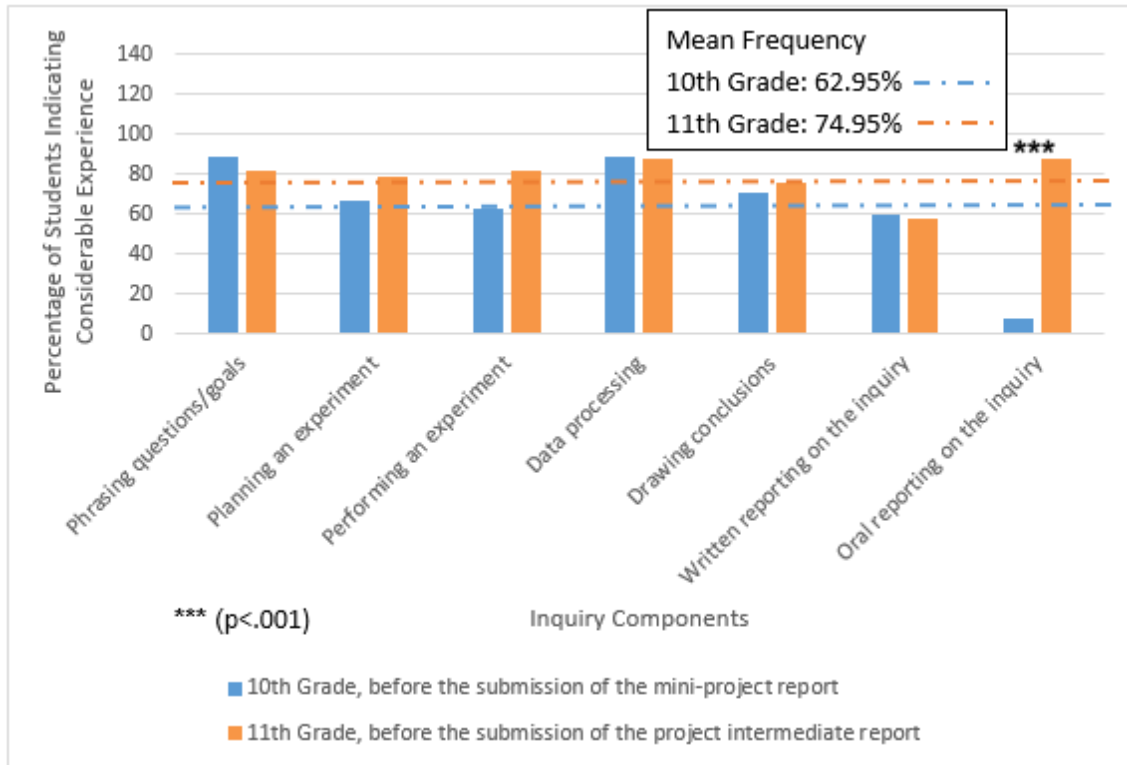


Figure 10: Reporting of Students on the **Considerable Experience** in the Performance of the Different Inquiry Components – Comparison between the Preparation Stage (N=27) and the Intermediate Stage of the Inquiry Project (N=33)

In the above bar chart, there is a significant difference ($\chi^2=43.15(14)$; $p<.001$) between the preparation stage and the intermediate stage in the inquiry project in the percentage of students who indicate considerable experience in the performance of the inquiry components presented in the figure, as follows:

- It was found that there is a significant increase ($p<.001$) in the component of oral reporting on the inquiry:
 - In this component, in addition to the increase of the significance, while in the preparation stage few students (under the mean frequency) report considerable experience, in the intermediate stage many students (above the mean frequency) report this.
- A significance change ($p>.05$) was not found in the rest of the components: phrasing questions/goals, planning an experiment, performing an experiment, data processing, drawing conclusions, and written reporting on the inquiry.

- In all these components, with the exception of the written reporting on the inquiry, both in the preparation stage and in the intermediate stage, many students (above the mean frequency) reported considerable experience.
- In the component of written reporting on the inquiry, both in the preparation stage and in the intermediate stage, few students (under the mean frequency) reported considerable experience.

The following figure represents the reporting of students on the **considerable difficulty** in the performance of the different inquiry components – comparison between the preparation stage for the inquiry project (in the second half of the tenth grade, N=27, before the submission of the mini-project report, from the Inquiry Skills Questionnaire) and the intermediate stage (in the second half of the eleventh grade, N=33, before the submission of the intermediate report of the project, from the Summative Questionnaire).

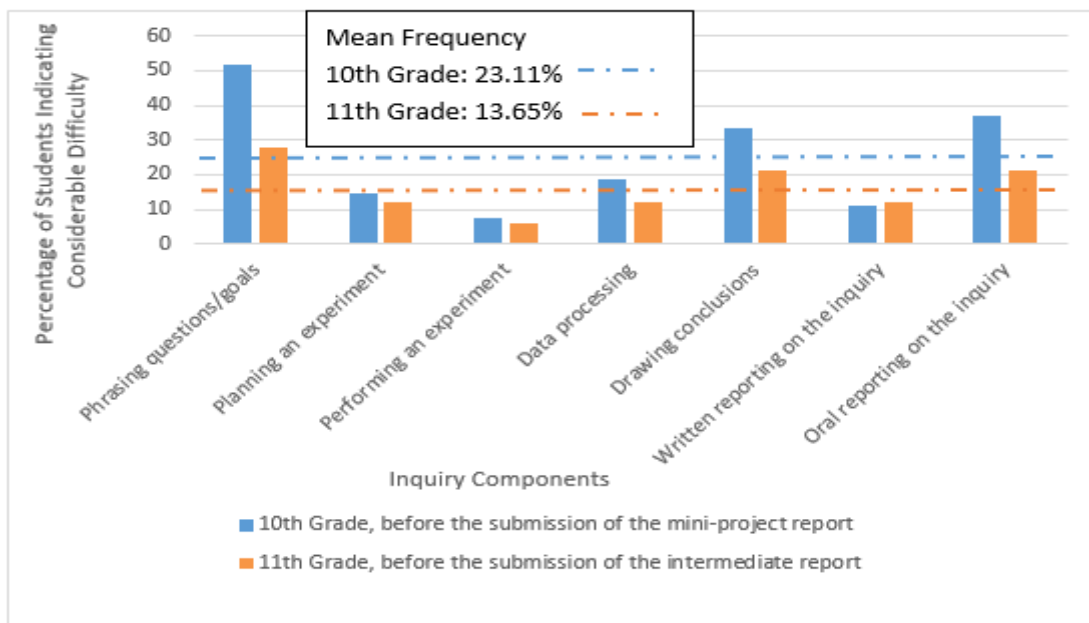


Figure 11: Reporting of Students on the **Considerable Difficulty** in the Performance of the Different Inquiry Components – Comparison between the Preparation Stage (N=27) and the Intermediate Stage of the Inquiry Project (N=33)

In the above bar chart, there is no significant difference ($p > .05$) between the preparation stage and the intermediate stage in the inquiry project in the percentage of students who indicate considerable difficulty in the performance of the inquiry components presented in the figure, as follows:

- A significant change was not found ($p > .05$) in all the inquiry components presented in the above figure.
 - The components of phrasing questions/goals, drawing conclusions, and oral reporting on the inquiry constituted a challenge for the students, both in the preparation stage and in the intermediate stage, and many students (above the mean frequency) reported considerable difficulty, but it appears that in the three components there is a trend of a decline in the percentage of the students indicating considerable difficulty.
 - In the components of planning an experiment, performing an experiment, data processing, and written reporting on the inquiry both in the preparation stage and in the intermediate stage few students (below the mean frequency) report considerable difficulty.

3.1.4.1.2 Comparison between Stage 2 (Intermediate Stage) and Stage 3 (Final Stage) – Experience and Challenge of Students in the Performance of the Inquiry Components

The following figure represents the reporting of students on the **considerable experience** in the performance of inquiry components – comparison between the intermediate stage (in the second half of the eleventh grade, N=33, before the submission of the intermediate report of the project, from the Summative Questionnaire) and the final stage (in the second half of the twelfth grade, N=34, before the submission of the summative report, from the Summative Questionnaire (repeat)).

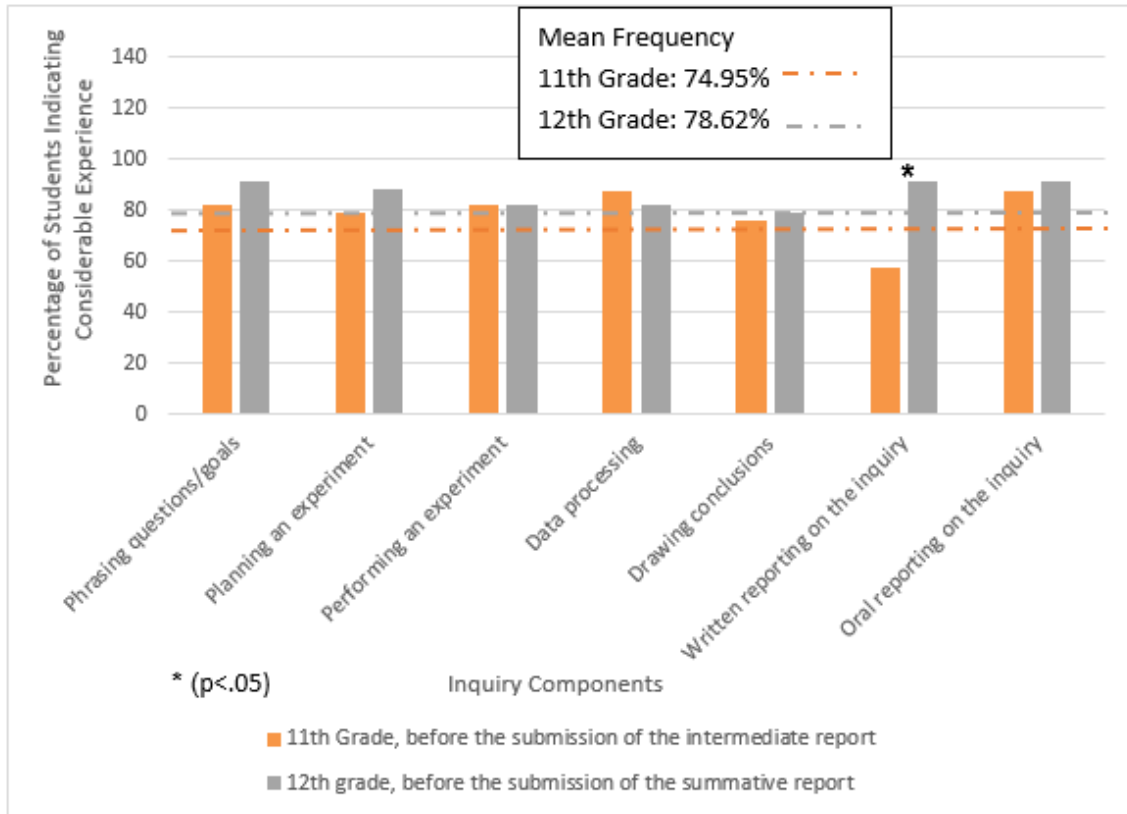


Figure 12: Reporting of Students on the **Considerable Experience** in the Performance of the Different Inquiry Components – Comparison between the Intermediate Stage (N=33) and the Final Stage (N=34) of the Inquiry Project

In the above bar chart, there is a significant difference ($\chi^2=13.07(14)$: $p<.05$) between the intermediate stage and the final stage in the inquiry project in the percentage of students who indicate considerable experience in the performance of the inquiry components presented in the figure, as follows:

- It was found that there is a significant increase ($p<.05$) in the component of written reporting on the inquiry.
 - In this component, in addition to the rise in significance, while in the intermediate stage few students (below the mean frequency) report considerable experience, in the final stage of the inquiry project more students (above the mean frequency) report this.

- A significant change ($p > .05$) was not found in the rest of the component: phrasing questions/goals, planning an experiment, performing an experiment, data processing, drawing conclusions, and oral reporting on the inquiry.
 - In all these components, both in the intermediate stage and in the final stage, many students (above the mean frequency) reported considerable experience.

The following figure represents the reporting of students on the **considerable difficulty** in the performance of inquiry components – comparison between the intermediate stage (in the second half of the eleventh grade, $N=33$, before the submission of the intermediate report of the project, from the Summative Questionnaire) and the final stage (in the second half of the twelfth grade, $N=34$, before the submission of the summative report, from the Summative Questionnaire (repeat)).

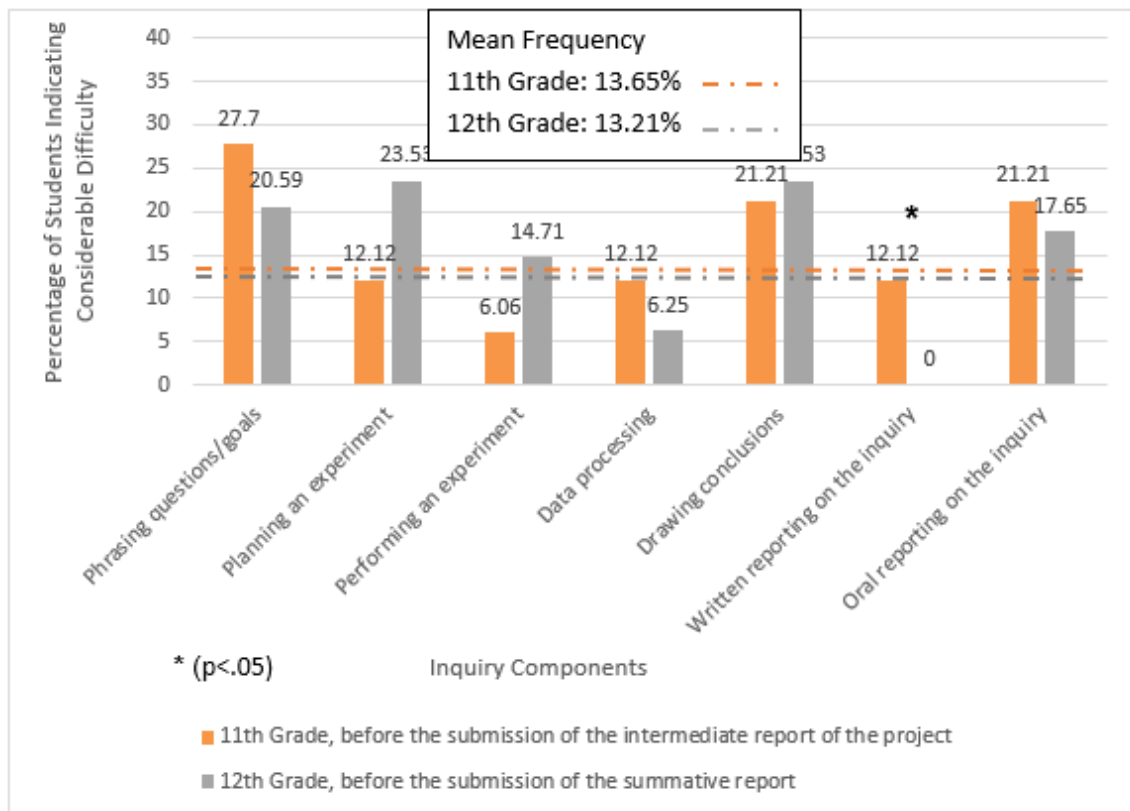


Figure 13: Reporting of Students on the **Considerable Difficulty** in the Performance of the Different Inquiry Components – Comparison between the Intermediate Stage ($N=33$) and the Final Stage ($N=34$) of the Inquiry Project

In the above bar chart, there is no significant difference ($p > .05$) between the intermediate stage and the final stage in the inquiry project in the percentage of students who indicate considerable difficulty in the performance of the inquiry components presented in the figure, as follows:

- It was found that there is a significant decrease ($p < .05$) in the component of written reporting on the inquiry.
 - In this component, in addition to a decline in significance, both in the intermediate stage and in the final stage, few students (below the mean frequency) report considerable difficulty.
- A significant difference ($p > .05$) was not found in the components of phrasing questions/goals, planning an experiment, performing an experiment, data processing, drawing conclusions, and oral reporting on the inquiry.
 - In the components of phrasing questions/goals, drawing conclusions, and oral reporting on the inquiry, there is no significant change, but both in the intermediate stage and in the final stage many students (above the mean frequency) reported considerable difficulty and these components constitute a challenge for students.
 - In the components of planning an experiment and performing an experiment, there is no significant change, but while in the intermediate stage few students (below the mean frequency) report considerable difficulty, in the final stage many students (above the mean frequency) report this. It can be seen that these components also constituted a challenge for students towards the final stage of the inquiry work.
 - In the component of data processing, both in the intermediate stage and in the final stage, few students (below the mean frequency) report considerable difficulty.

3.1.4.2 Experience and Challenge of Students in the Performance of Additional Inquiry Components Examined in the Last Two Stages

3.1.4.2.1 Comparison between Stage 2 (Intermediate Stage) and Stage 3 (Final Stage) – Experience and Challenge of Students in the Performance of the Inquiry Components

The following figure represents the reporting of students on the **considerable experience** in the performance of the inquiry components in eight **additional inquiry** components – between the intermediate stage of the inquiry project (in the second half of the eleventh grade, N=33, before the submission of the intermediate report of the project, from the Summative Questionnaire) and the final stage (in the second half of the twelfth grade, N=34, before the submission of the summative report, from the Summative Questionnaire (repeat)).

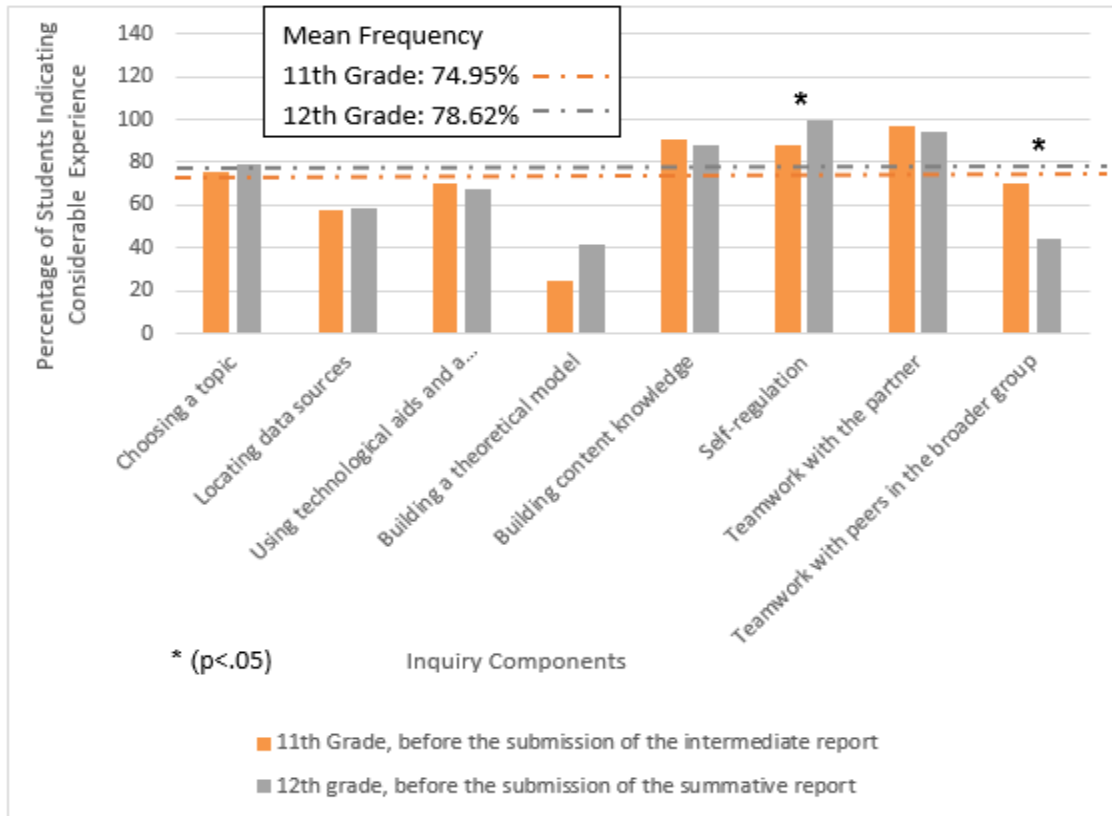


Figure 14: Reporting of Students on the **Considerable Experience** in the Performance of **Additional Inquiry** Components – Comparison between the Intermediate Stage (N=33) and the Final Stage (N=34) of the Inquiry Project

In the above bar chart, there is no significant difference ($p > .05$) between the intermediate stage and the final stage in the inquiry project in the percentage of students who indicate considerable experience in the performance of the inquiry components presented in the figure, as follows:

- It was found that there is a significant increase ($p < .05$) in the component of self-regulation.
 - In this component, in addition to the significant increase, both while in the intermediate stage and in the final stage of the inquiry project, many students (above the mean frequency) report considerable experience.
- A significant difference ($p > .05$) was not found in the components of choosing a topic, locating information sources, using technological aids and a computerized library, building a theoretical model, building content knowledge, teamwork with the partner.
 - In the component of choosing a topic, building content knowledge, and teamwork with the partner both in the intermediate stage and in the final stage of the inquiry project many students (above the mean frequency) report considerable experience.
- A significant change ($p > 0.5$) was not found in the components of choosing a topic, locating information sources, using technological aids and a computerized laboratory, building a theoretical model, building content knowledge, teamwork with the partner.
 - In the components of choosing a topic, building content knowledge, and teamwork with the partner both in the intermediate stage and in the final stage many students (above the mean frequency) reported considerable experience.
 - In the components of locating information sources, using technological aids and a computerized laboratory, and building a theoretical model, both in the intermediate stage and in the final stage few students (below the mean frequency) reported considerable experience.
- It was found that there was a significant decline ($p < .001$) in the component of teamwork with peers in the broader group.
 - In this component, in addition to the significant decline, both in the intermediate stage and in the final stage few students (below the mean frequency) reported considerable experience.

The following figure represents the reporting of students on the **considerable difficulty** in the performance of the inquiry components in eight additional inquiry components – between the intermediate stage of the inquiry project (in the second half of the eleventh grade, N=33, before the submission of the intermediate report of the project, from the Summative Questionnaire) and the final stage (in the second half of the twelfth grade, N=34, before the submission of the summative report, from the Summative Questionnaire (repeat)).

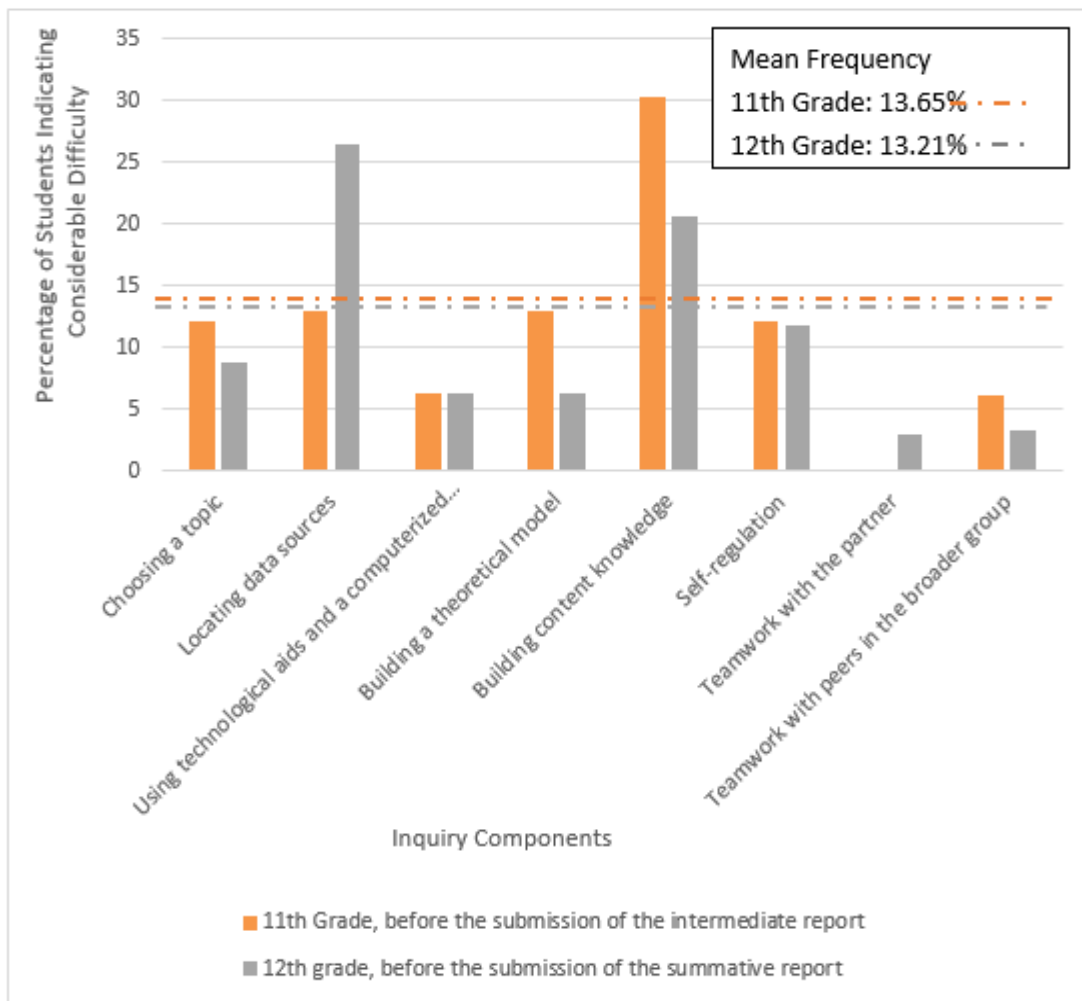


Figure 15: Reporting of Students on the **Considerable Difficulty** in the Performance of **Additional Inquiry** Components – Comparison between the Intermediate Stage (N=33) and the Final Stage (N=34) of the Inquiry Project

In the above bar chart, there is no significant difference ($p > .05$) between the intermediate stage and the final stage in the inquiry project in the percentage of students who indicate considerable difficulty in the performance of the inquiry components presented in the figure, as follows:

- A significant difference ($p > .05$) was not found in all the inquiry components presented in the above figure.
 - In the component of building content knowledge, while there is no significant change, both in the intermediate stage and in the final stage many students (above mean frequency) reported considerable difficulty, and this component constituted a challenge for the students.
 - In the components of choosing a topic, using technological aids and computerized laboratory, building a theoretical model, self-regulation, teamwork with the partner, and teamwork with peers in the broader group both in the intermediate stage and in the final stage few students (below the mean frequency) reported considerable difficulty and fewer said this constituted a challenge.
 - In the component of locating information sources, there is no significant change but while in the intermediate stage few students (above the mean frequency) report this, in the final stage many students (above the mean frequency) report this. It is possible to see that this component too constituted a challenge for students towards the final stage of the inquiry work.

3.1.5 Main Findings – Students’ Perception of Their Experience and Challenge in the Performance of the Inquiry Components in the Different Stages in the Program

3.1.5.1 Main Findings of the Quantitative Analysis – The Students’ Perception of the Degree of Their Experience and Challenge in the Different Inquiry Components

3.1.5.1.1 Students’ Perception of the Degree of Their Experience and Challenge of the Performance of the Inquiry Components Examined in the Three Stages

This subchapter presents main findings of the percentage of the students who indicate considerable experience/difficulty in the different inquiry components relative to the mean frequency and emphasis on the significant changes between the stages in

particular between the preparation stage and the final stage. To see the overall picture of the degree of experience and degree of challenge of the students in the performance of the inquiry components examined in three stages, the following figures are presented.

The following figure represents an overall picture of the **students' reporting on the considerable experience in the performance of the inquiry components** in the different stages in the program: preparation stage of the inquiry project (in the second half of the tenth grade, N=27, before the submission of the mini-project), the intermediate stage (in the second half of the eleventh grade, N=33, before the submission of the intermediate report on the project), and the final stage (in the second half of the twelfth grade, N=34, before the submission of the summative report). It is possible to see in the figure every inquiry component throughout the different stages in the program through the line. We note that the line does not represent the pace of development but is there for the convenience of following up after a certain component.

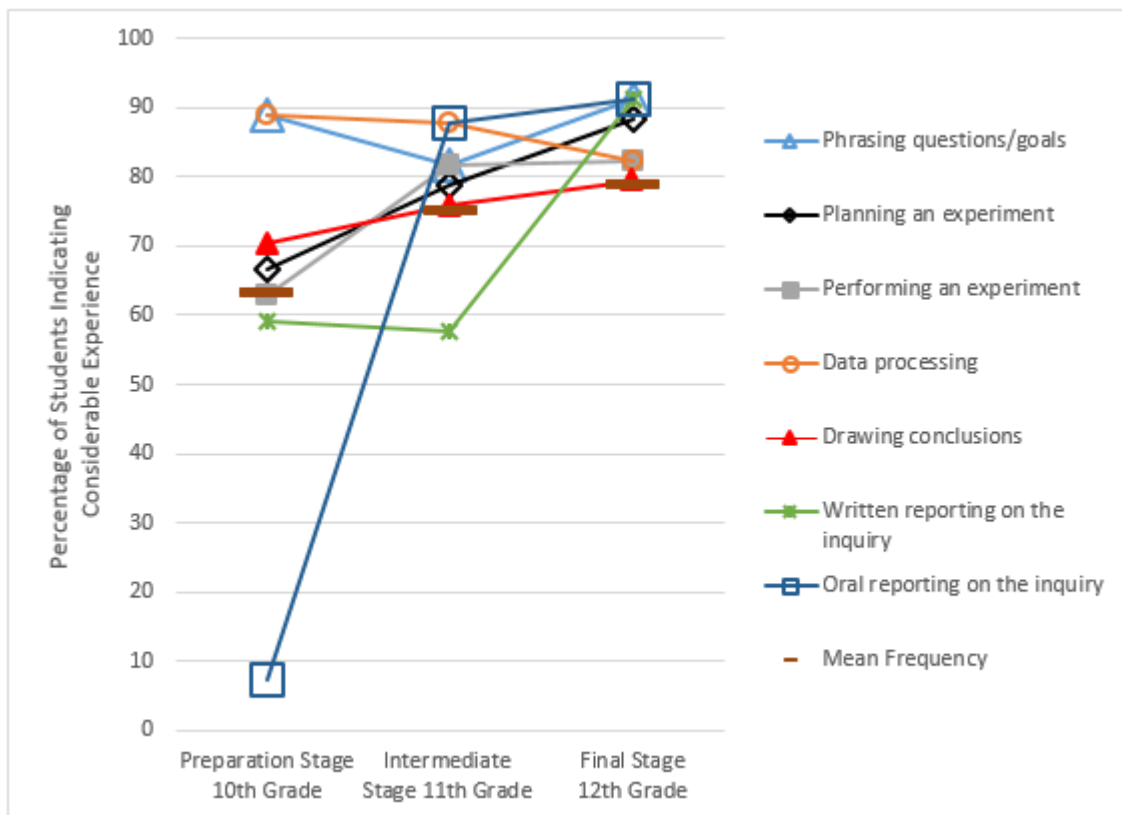


Figure 16: **Overall Picture** – Report of Students on the **Considerable Experience** in the Performance of Inquiry Components in Different Stages in the Program: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34) of the Inquiry Work

We will focus on the significant changes in the degree of experience between the preparation stage and the final stage of the inquiry work. The following figure represents the reporting of students on the experience in the performance of inquiry components – comparison between the preparation stage of the inquiry project (in the second half of the tenth grade, N=27, before the submission of the mini-project, from the Inquiry Skills Questionnaire) and the final stage (in the second half of the twelfth grade, N=34, before the submission of the summative report, from the Summative Questionnaire (repeat)).

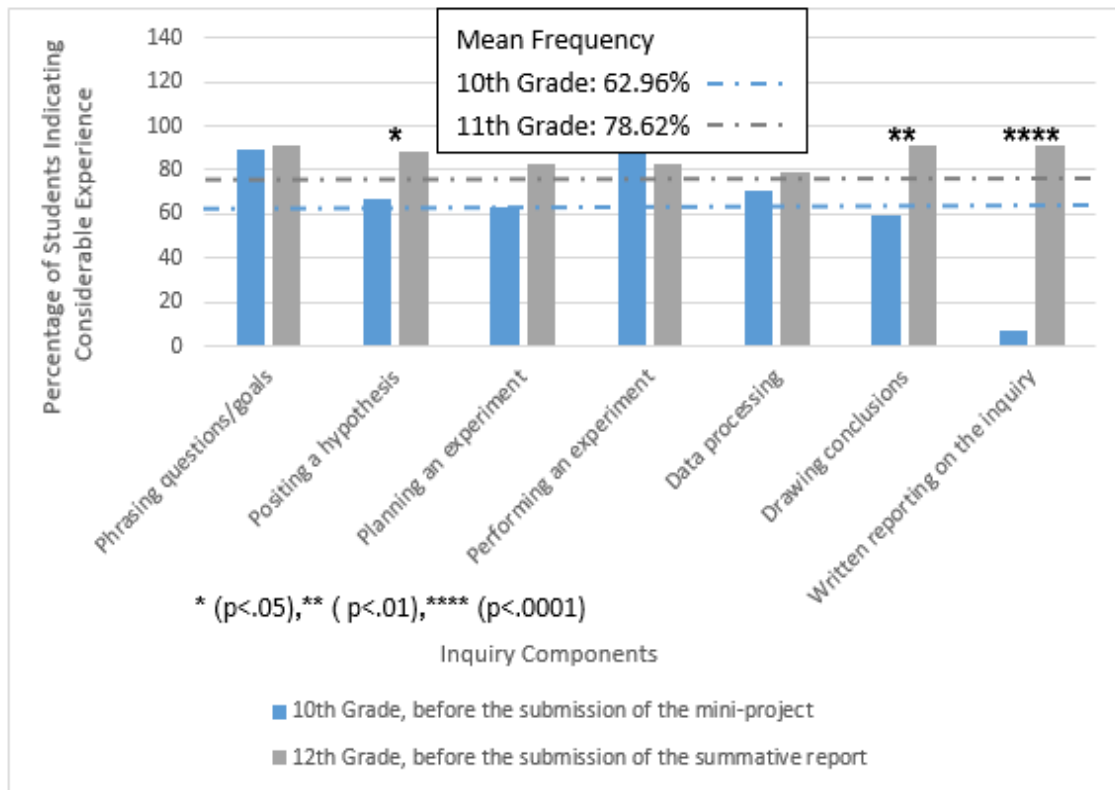


Figure 17: Report of Students on the **Considerable Experience** in the Different Inquiry Components – Comparison between Preparation Stage (N=27) and Final Stage (N=34) of the Inquiry Work

In the above bar chart, there is no significant difference ($\chi^2=59.56$ (14): $p<.0001$) between the preparation stage and the final stage in the inquiry project in the percentage of students who indicate considerable difficulty in the performance of the inquiry components presented in the figure, as follows:

- It was found that there is a significant increase ($p < .05$) in the components of planning an experiment, written reporting on the inquiry, and oral reporting on the inquiry.
 - In the component of planning an experiment both in the preparation stage and in the final stage many students (above the mean frequency) report considerable experience.
 - In the components of written reporting on the inquiry and oral reporting on the inquiry, in addition to a rise in significance, while in the preparation stage few students (below the mean frequency) report considerable experience, in the final stage many students (above the mean frequency) report this.
- A significant change ($p > .05$) was not found in the components of phrasing goals/questions, performance of an experiment, data processing, and drawing conclusions.
 - In all these components, both in the preparation stage and in the final stage many students (above the mean frequency) reported considerable experience.

In addition, the following presents significant changes in the degree of experience between the stage before the start of the program and the final stage of the inquiry work.

The following figure represents the reporting of students on the **considerable experience** in the performance of inquiry components – comparison between the pre-program-stage before the start of the program in the first half of the tenth grade, $N=33$ (from the Preliminary Questionnaire, see appendix number 1.1) and the final stage in the second half of the twelfth grade, $N=34$, before the submission of the summative report (from the Summative Questionnaire (repeat), see appendix number 1.4).

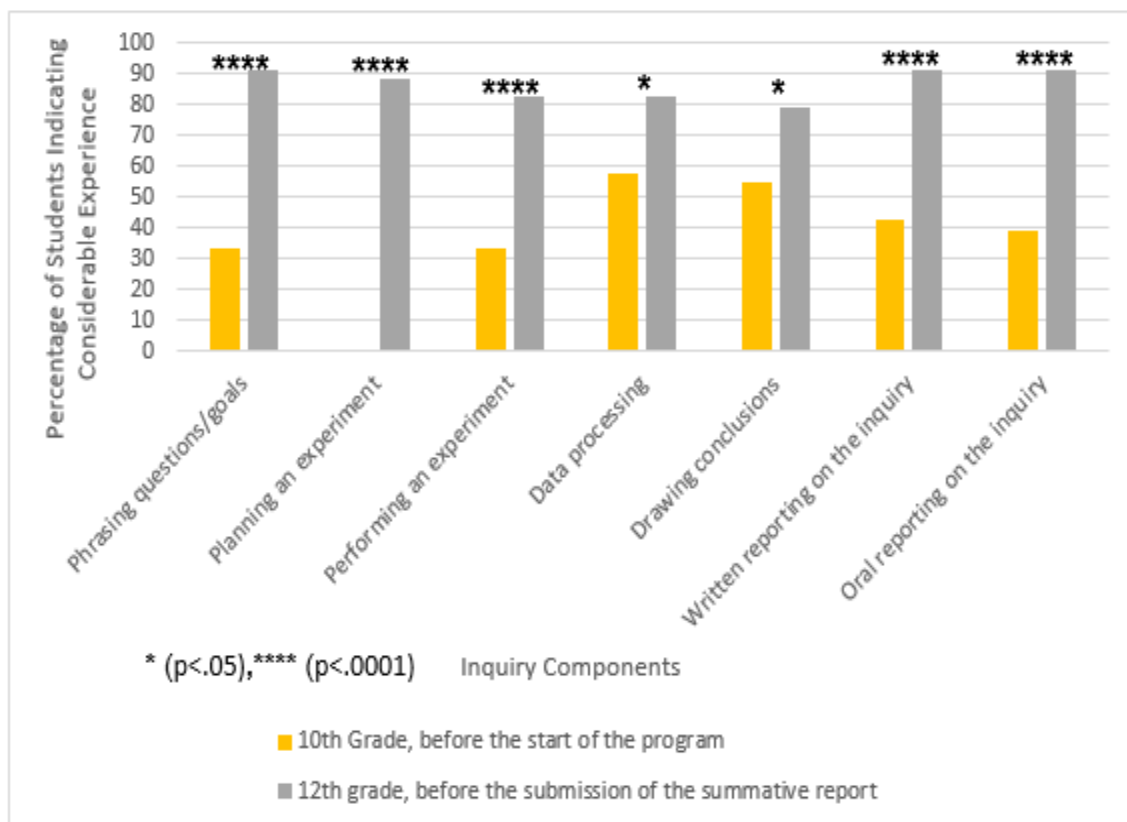


Figure 18: Report of Students on the **Considerable Experience** in the Performance of Different Inquiry Components – Comparison between the Stage between Pre-Program (N=33) and the Final Stage of the Inquiry Work (N=34)

In the above bar chart, there is a very significant difference ($\chi^2=140.79(14)$: $p<.0001$) between the stage before the start of the program and the final stage in the inquiry project in the percentage of students who indicate considerable experience in the performance of the inquiry components presented in the figure, as follows:

- It was found that there is a significant increase ($p<.05$) in the components of planning an experiment, written reporting on the inquiry, and oral reporting on the inquiry.
- It was found that there is a significant increase ($p<.0001$) in the components of phrasing questions/goals, planning an experiment, performing an experiment written reporting on the inquiry, and oral reporting on the inquiry.

The following figure represents an overall picture of the **students' reporting on the considerable difficulty in the performance of the inquiry components** in different stages in the program: preparation stage of the inquiry project (in the second half of the tenth grade, N=27, before the submission of the mini-project report), the intermediate stage (in the second half of the eleventh grade, N=33, before the submission of the intermediate project report), and the final stage (in the second half of the twelfth grade, N=34, before the submissions of the summative report). It is possible to follow in one graph after each inquiry component throughout the different stages in the program through the line. We note that the line does not represent the pace but is only for the convenience of following up after a certain component.

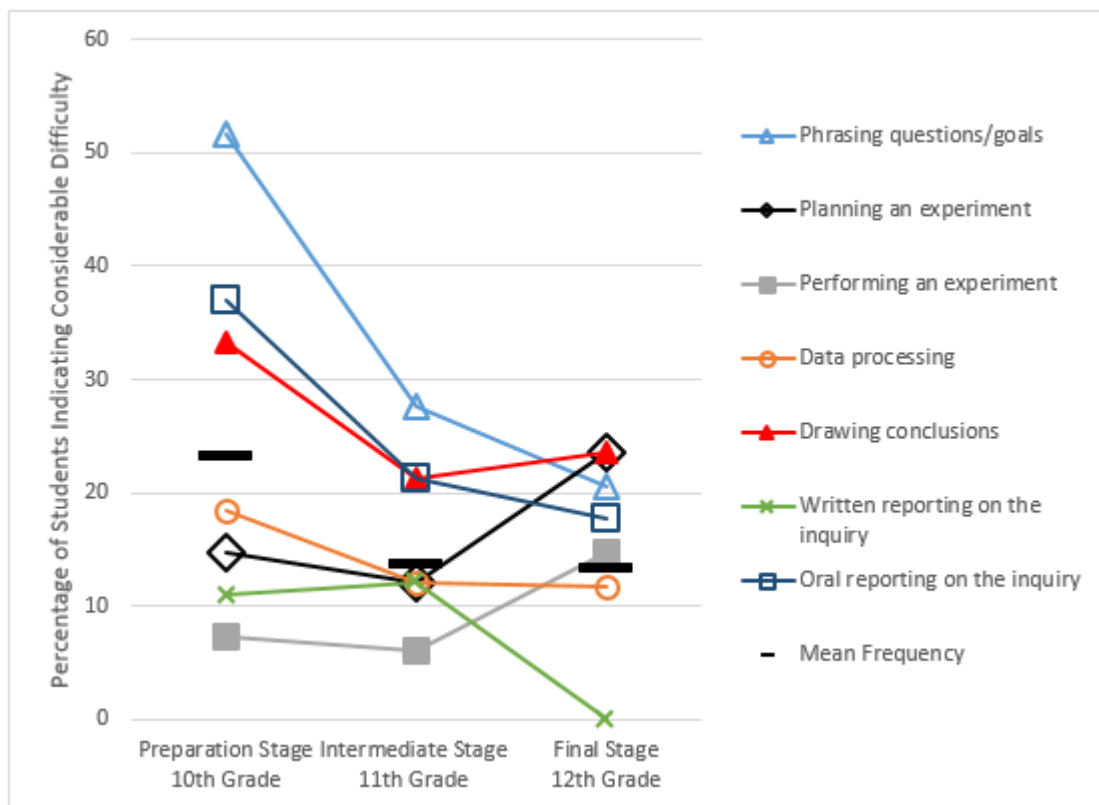


Figure 19: **Overall Picture** - Report of Students on the **Considerable Difficulty** in the Performance of Inquiry Components in the Different Stages of the Program – Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34) of the Inquiry Work

We focus on significant changes in the degree of challenge between the preparation stage and the final stage of the inquiry work.

The following figure represents the students' reporting on the **considerable difficulty** in the performance of the inquiry components – comparison between the preparation stage of the inquiry project (in the second half of the tenth grade, N=27, before the submission of the mini-project report, from the Inquiry Skills Questionnaire) and the final stage (in the second half of the twelfth grade, N=34, before the submission of the summative report, from the Summative Questionnaire (repeat)).

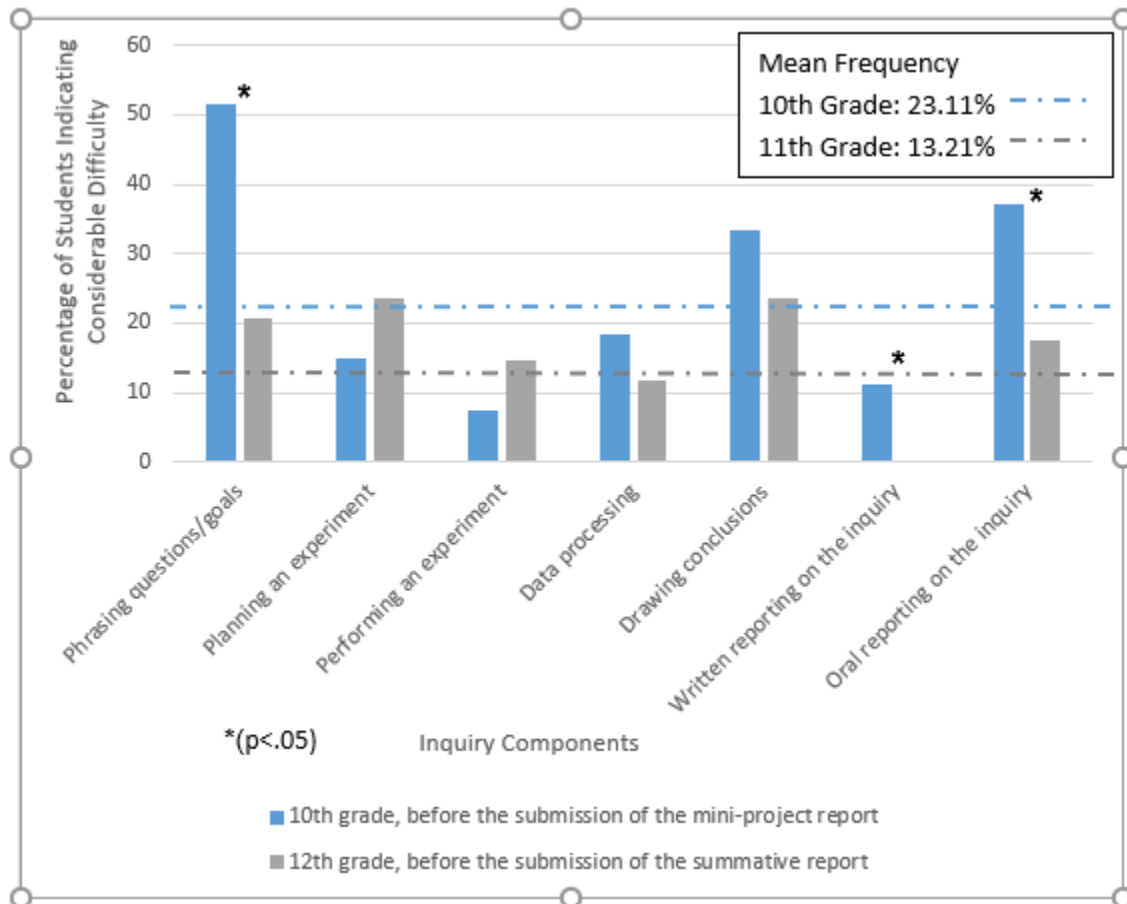


Figure 20: Report of Students on the **Considerable Difficulty** in the Performance of the Different Inquiry Components – Comparison between the Preparation Stage (N=27) and Final Stage (N=34) of the Inquiry Work

In the above bar chart, there is a very significant difference ($\chi^2=32.38(14)$; $p<.01$) between the preparation stage and the final stage in the inquiry project in the percentage of students who indicate considerable difficulty in the performance of the inquiry components presented in the figure, as follows:

- It was found that there is a significant decrease ($p < .05$) in the components of phrasing questions/goals and written reporting on inquiry.
 - In the component of phrasing questions/goals, despite the significant decrease, both in the preparation stage and in the final stage many students (above the mean frequency) reported considerable difficulty and moreover in the final stage not one student reported this.
- A significant change ($p > .05$) was not found in the components of planning an experiment, performing an experiment, data processing, drawing conclusions, and oral reporting on the inquiry.
 - In the components of drawing conclusions and oral reporting on the inquiry both in the preparation stage and in the final stage many students (above the mean frequency) reported considerable difficulty.
 - In the components of planning an experiment and performing an experiment, there is no significant change, but in the preparation stage few students (under the mean frequency) report considerable difficulty and in the final stage many students (above the mean frequency) report this and that it is possible to see that these components constituted a challenge for students towards the final stage of the inquiry work.
 - In the component of data processing both in the preparatory stage and in the final stage few students (below the mean frequency) report considerable difficulty.

To summarize, three inquiry components that constituted a challenge for many students (above the mean frequency) throughout all the inquiry stages (at three different points in time in the program) are phrasing questions/goals, drawing conclusions, oral reporting on the inquiry. Although in the component of the phrasing of questions/goals in the percentage of the students that indicate considerable difficulty is high (above the mean frequency), throughout all the inquiry stages there is a significant decrease between the preparation stage and the final stage of the inquiry work in this component. In the components of drawing conclusions and oral reporting of the inquiry there is a significant change between the stages. It is possible to see that also in the two inquiry components phrasing goals/questions and drawing conclusions, many of the students (above the mean

frequency) reported the considerable experience throughout all the inquiry stages, from the preparation stage to the final stage of the inquiry work while in the oral reporting on the inquiry only in the last stages of the inquiry work the students reported this and there is a significant increase between the preparation stage and the final stage of the inquiry work in this component.

The components of planning an experiment and performing an experiment constituted a challenge for many students, but only in the final stage of the project. It is possible to see also throughout all the inquiry stages (at three different points of time in the program) that many students (above mean frequency) reported considerable experience in these components and even in the planning of an experiment there is a significant increase between the stage of the preparation and the final stage of the inquiry work.

In contrast, few students (below the mean frequency) reported considerable difficulty throughout all the inquiry stages (at three different points of time in the program) in the inquiry components of data processing and written reporting on the inquiry, and there is a decline in the two components in the percentage of students who indicate considerable difficulty between the preparation stage and the final stage of the inquiry process, when in the component of written reporting on the inquiry there is a significant decrease. In addition, it is possible to see that throughout all the inquiry stages (at three different points of time in the program) many students (above the mean frequency) reported considerable experience in the component of data processing, when in the component of written reporting on the inquiry only towards the final stage did the students report this and in this component there is a significant increase between the preparation stage and the final stage of the inquiry process.

In all the inquiry components presented here the students report considerable experience in the performance of these components more than before the beginning of the program and even the changes are very significant. In other words, the Research Physics Program constituted an opportunity for students to experience different inquiry practices as opposed to other frameworks in which the students are found, for instance, the school framework.

3.1.5.1.2 Students' Perception of the Degree of Their Experience and Challenge in the Performance of the Additional Inquiry Components Examined in the Last Two Stages

This subchapter presents main findings of the percentage of students who indicate considerable experience/difficulty in the additional inquiry components relative to the mean frequency. To see the overall picture of the degree of experience and the degree of challenge of the students in the performance of the **additional inquiry components**, we will look at the following figures.

The following figure represents an overall picture of the **students' reporting on the considerable experience in the performance of the additional inquiry components** in the last stages of the inquiry work: the intermediate stage of the inquiry project (in the second half of the eleventh grade, N=33, before the submission of the intermediate report on the project) and the final stage of the inquiry project (in the second half of the twelfth grade, N=34, before the submission of the summative report). We note that the dotted line does not represent the pace of development but is only for convenience of the follow-up after a certain component.

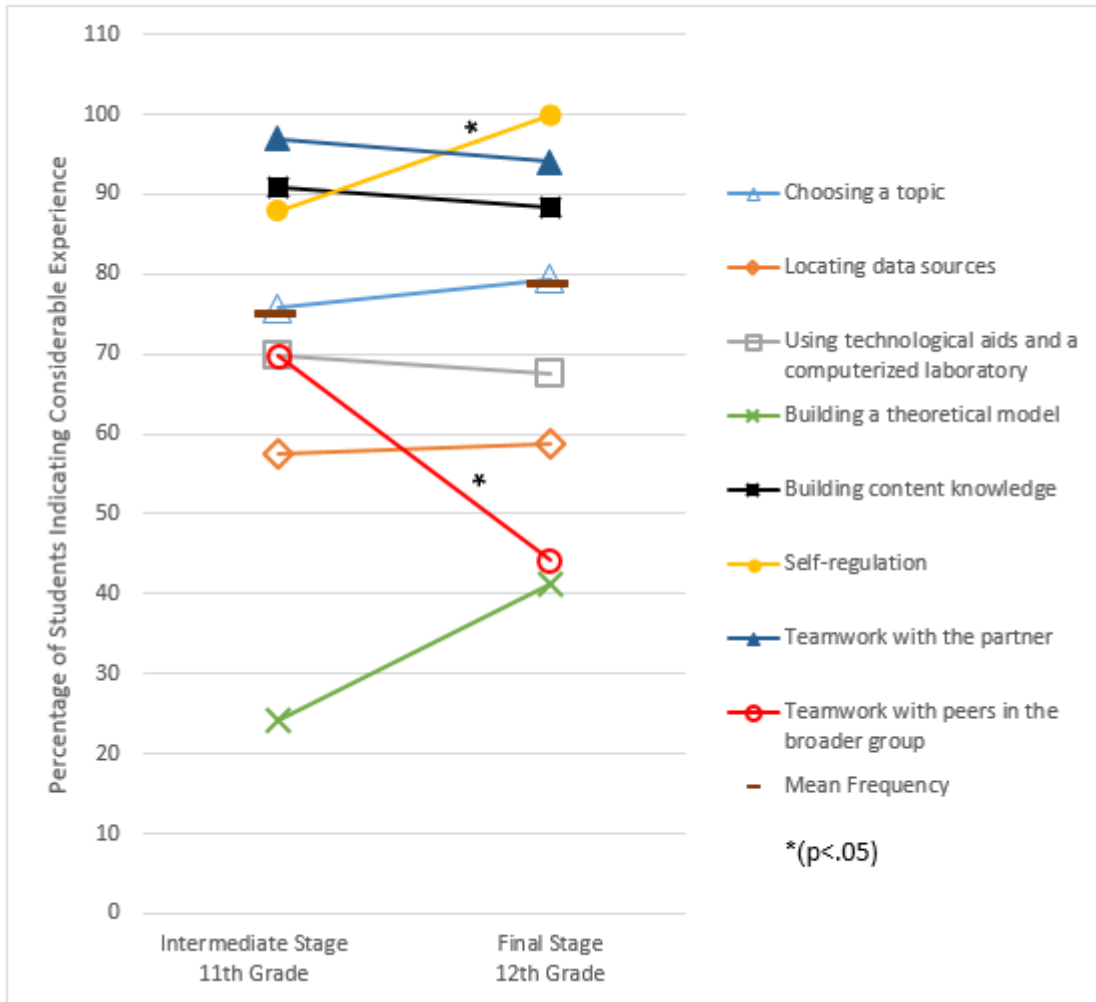


Figure 21: **Overall Picture** - Report of Students on the **Considerable Experience** in the Performance of **Additional Inquiry Components** in the Different Stages of the Program – Intermediate Stage (N=33) and Final Stage (N=34) of the Inquiry Work

The following figure represents a picture of the **students’ reporting on the considerable difficulty in the performance of the additional inquiry components** in the last stages of the inquiry work: we comment that the line does not represent the pace but is only for the convenience of follow up after the particular component.

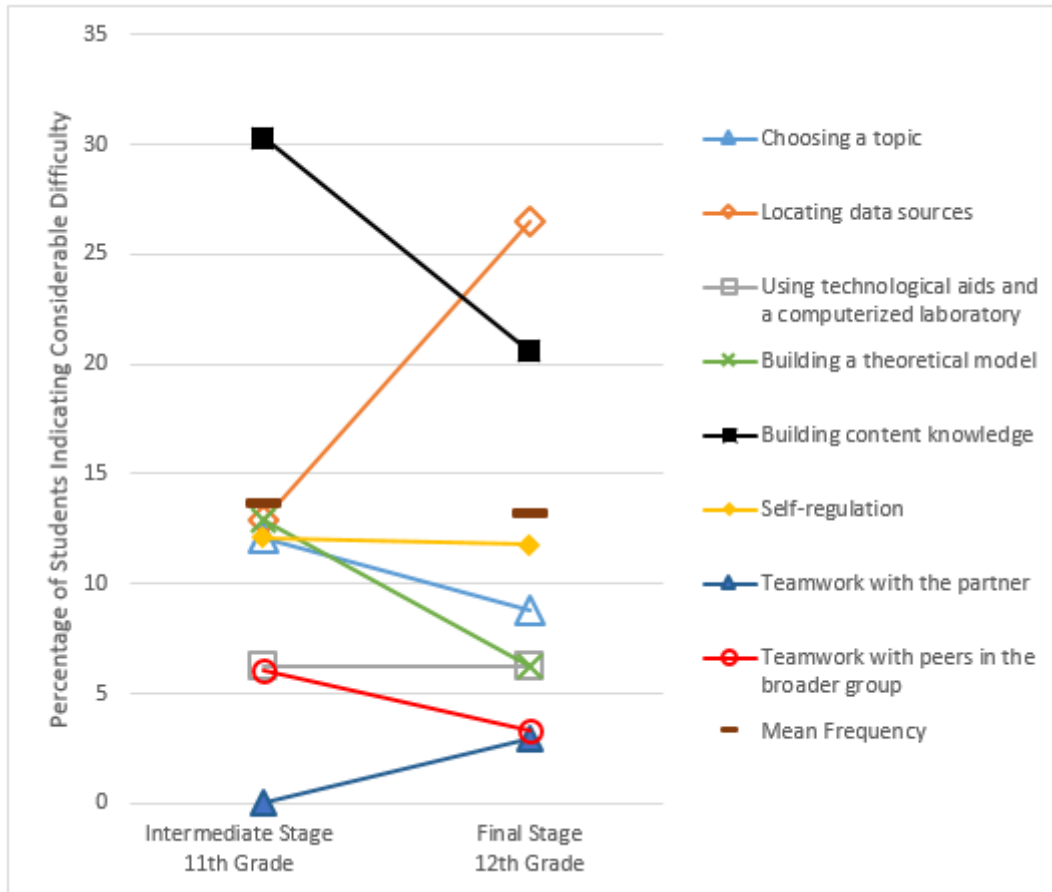


Figure 22: **Overall Picture** - Report of Students on the **Considerable Difficulty** in the Performance of **Additional** Inquiry Components in the Different Stages of the Program – Intermediate Stage (N=33) and Final Stage (N=34) of the Inquiry Work

To summarize, the component of the building of knowledge content constituted a challenge in the last two stages of the inquiry work. Many students (above the mean frequency) experienced considerable difficulty both in the intermediate stage and in the final stage of the inquiry work, although there is a trend of decline towards the final stage of the inquiry work. In addition, it is also possible to see that many students (above the mean frequency) reported considerable experience in this component in the last two stages of the inquiry work.

In contrast, few students (under the mean frequency) reported considerable difficulty in the last stages of the inquiry work in the components of choosing a topic, using technological aids and a computerized laboratory, building a theoretical model, self-regulation, teamwork with the partner, and teamwork with peers in the broader group, when the percentage of students in the component of teamwork with the partner is the lowest

(despite the increase towards the final stage of the inquiry work). In addition, it is possible to see from these aforementioned components that many students (above the mean frequency) reported the considerable experience in the inquiry components of choosing a topic, self-regulation, and teamwork with the partner and especially in self-regulation there is a significant rise from the intermediate stage to the final stage of the inquiry work. In the components of building a theoretical model, using technological aids and a computerized laboratory and teamwork with peers in the broader group few students (under the mean frequency) report this, and especially in teamwork with peers there is a significant decline and the percentage of students who note the considerable experience from the intermediate stage to the final stage of the research process. In the experience in the component of building a theoretical model, although there is a trend of increase in the final stage of the research, the percentage of students who indicate considerable experience in this component is still the lowest in the two stages.

3.1.5.2 Main Findings of the Qualitative Analysis – Main Challenges that Arose from the Students’ Reports in Each Inquiry Component in the Different Stages of the Inquiry Work

According to the findings presented in the previous section, we will divide the inquiry components into groups: components that constituted a challenge for many students (above the mean frequency) throughout most of the inquiry stages, components that constituted a challenge for many students (above the mean frequency) only in the final stage of the inquiry work, and inquiry components in which a few students (under the mean frequency) reported challenge (great difficulty) throughout most of the inquiry stages.

In each one of the groups, there is description of the main challenges in the different inquiry components and in which stage they were reported. We will summarize the process that the students go through during the inquiry work through tables. From the tables, it will be possible to look at the process the students go through throughout the inquiry work, the different difficulties in every stage, and the shared difficulties of the different stages with which the students coped during the inquiry work.

1. The inquiry components that constituted a challenge for many students (above the mean frequency) throughout most of the inquiry stages are: phrasing questions/goals, drawing conclusions, oral reporting on the inquiry, and building content knowledge. (The components phrasing questions/goals, drawing conclusions, and oral reporting of the inquiry constituted a challenge throughout all the stages of the inquiry [stages 1, 2, and 3] and the component of building content knowledge constituted a challenge in the last two stages of the inquiry work [stages 2 and 3]. We note that data was not collected in stage 1 about the component of building content knowledge, and the reasons are detailed in the preface of the chapter of the findings of part A.)

The following table presents the main difficulties that arose from the students' reports on the inquiry components phrasing questions/goals, drawing conclusions, oral reporting on the inquiry, and building content knowledge and the stage in which they were reported (stage 1 – the stage of preparation for the inquiry project, stage 2 – the intermediate stage of the inquiry work, stage 3 – the final stage of the inquiry work).

Table 5: The Main Difficulties that Arose from the Students' Reports in the Inquiry Components – Phrasing Questions/Goals, Drawing Conclusions, Oral Reporting of the Inquiry, and Building Content Knowledge (Sigron, M)

Inquiry components	The Students' Main Difficulties during the Inquiry Work	Stage
Phrasing questions/goals	<ol style="list-style-type: none"> 1. General difficulty with transferring the thought to phrasing in the form of a question/goal 2. Difficulty with preliminary locating and identifying the factors that influence the phenomenon, especially when there is no previous knowledge on the phenomenon 3. Difficulty choosing the inquiry question, so it will be interesting and open and will lead to in-depth investigation, and creativity is needed for this 	1
	<ol style="list-style-type: none"> 4. Difficulty with focusing the inquiry question and preventing dispersion 	2, 3
Drawing conclusions	<ol style="list-style-type: none"> 1. Difficulty with finding a relationship between two factors 2. Difficulty with implementing thinking strategies on a high level (such as understanding, analysis, and synthesis) to reach conclusions 	1
	<ol style="list-style-type: none"> 3. Difficulty when a theory relevant to the research is not found, upon which it is possible to base in the conclusions 4. Difficulty with when the theory is very complicated mathematically (for the students) for reaching conclusions 	2
	<ol style="list-style-type: none"> 5. Difficulty with comparing between theory and findings of the experiment, especially when there is a gap between them (when the results of the experiment are not commensurate with the theory) and it is necessary to provide an explanation 	1, 2, 3
Oral reporting on the inquiry	<ol style="list-style-type: none"> 1. General difficulty with conveying the thought into oral expression 2. Difficulty with the mastery of the knowledge accumulated by the research during the presentation 	1
	<ol style="list-style-type: none"> 3. Difficulty with meeting the time allotted for the presentation of the research 4. Fear that the oral presentation may harm the image of the quality of the project 	2
	<ol style="list-style-type: none"> 5. Coping with the fear, embarrassment, and pressure involved in standing up and presenting in front of an audience 	1, 2, 3
	<ol style="list-style-type: none"> 1. Difficulty with learning and understanding the contents required for the investigation of the phenomenon, especially when there is no prior knowledge on the research topics and the theoretical material is new for them 2. The coping with the complexity and high level of the theoretical material (in terms of the physics and/or mathematics) to reach a more in-depth understanding 3. Difficulty with independent learning of contents relevant to the research 	2, 3

2. **The three inquiry components that constituted a challenge for many students (above mean frequency) only in the final stage of the inquiry work are: locating information sources, planning an experiment, and performing an experiment.**

The following table presents the main difficulties that arose from the students' reports in the inquiry components of locating information sources, planning an experiment, and performing an experiment and the stage in which they were reported (stage 1 – the stage of preparation for the inquiry project, stage 2 – the intermediate stage of the inquiry work, stage 3 – the final stage of the inquiry work).

Table 6: The Main Difficulties that Arose from the Students' Reports in the Inquiry Components – Locating Information Sources, Planning an Experiment, and Performing an Experiment (Sigron, M)

Inquiry components	The Students' Main Difficulties during the Inquiry Work	Stage
Locating information sources	1. Lack of knowledge and experience in finding evaluated, quality, and high level information sources	2
	2. Difficulty with the multiplicity of information sources when the phenomenon is composed of sub-phenomena and many components	
	3. Finding a low number of sources relevant to the researched phenomenon, primarily when the researched phenomenon is not common and because of their little experience in this component	2, 3
Planning an experiment	1. Difficulty with performing isolation of variables in the process of the planning of the experiment	2, 3
	2. Coping with the dynamism of the experiment planning to increase the effectiveness and improve the experiment system	
	3. Difficulty with planning additional experiments that will bring up quantitative and not only qualitative data	3
Performing an experiment	1. Coping with the existence of random mistakes in the performance of an experiment, such as human error	1
	2. Difficulty with finding the equipment required for the experiment in the laboratory in an independent manner	2
	3. Difficulty with building the system and partially operating it independently, which derives from the lack of familiarity with the topic and with the system components	
	4. Difficulty with building the system of the experiment so it will enable performance of accurate measurements (because of the existence of factors of error in the experiment, limitation of the experiment system, and lack of equipment and means in the laboratory)	3
	5. Coping with the dynamism of performing the experiment in the research process, which is expressed in the performance of repeat experiments and the improvement of the experiment system	

3. The inquiry components in which a few students (under the mean frequency) reported a challenge (great difficulty) throughout most of the inquiry stages:

- The inquiry components in which a few students (under the mean frequency) reported a challenge (great difficulty) throughout all of the inquiry stages (stages 1, 2, and 3) are: **data processing and written reporting on the inquiry.**

The following table presents the main difficulties that arose from the students' reports in the inquiry components of data processing, oral reporting on the inquiry, and the stage in which they were reported (stage 1 – the stage of preparation for the inquiry project, stage 2 – the intermediate stage of the inquiry work, stage 3 – the final stage of the inquiry work).

Table 7: The Main Difficulties that Arose from the Students' Reports in the Inquiry Components – Data Processing and Written Reporting on the Inquiry (Sigron, M)

Inquiry components	The Students' Main Difficulties during the Inquiry Work	Stage
Data Processing	1. Difficulty with building graphs in a computerized environment	1
	2. Difficulty with classifying data relevant to the inquiry question 3. Difficulty with the independent transition from raw data to complex data	2
	4. Difficulty with the collection and analysis of data, because of the large scope of the data	3
Written Reporting on the Inquiry	1. General difficulty with verbal phrasing, especially transition from graphical representation to verbal representation	1
	2. Difficulty with persevering in the continuous and consistent documentation of the research during the investigation (because of lack of time and/or resourcefulness)	2
	3. Difficulty with the summarization of the main points in the writing of the presentation	2, 3
	4. Difficulty with the verbal phrasing of the description of the components of the work, like the description of the experiments, the description of the conclusions, and the description of the reflection 5. Difficulty with the organization of the summative work, the ordering of the work components in a logical and interesting to read continuum	3

- In addition, the inquiry components in which few students (under the mean frequency) reported challenge (great difficulty) in the last two stages of the inquiry work (stages 2 and 3) are: **choosing a topic, using technological aids and a computerized**

laboratory, building a theoretical model, self-regulation, teamwork with the partner, and teamwork with peers in the broader group. (note that data was not collected about these components in the first stage, and the reasons for this are described in the preface of the chapter of the findings of part 3)

The following table presents the main difficulties that arose from the students' reports in the inquiry components of choosing a topic, using technological aids and a computerized laboratory, building a theoretical model, self-regulation, teamwork with the partner, teamwork with peers in the broader group, and what stage they were reported (stage 1 – the stage of the preparation for the inquiry project, stage 2 – the intermediate stage of the inquiry project, stage 3 – the final stage of the inquiry work).

Table 8: The Main Difficulties that Arose from the Students' Reports in the Inquiry Components – Using Technological Aids and a Computerized Laboratory, Building a Theoretical Model, Self-Regulation, Teamwork with the Partner, and Teamwork with Peers in the Broader Group (Sigron, M)

Inquiry components	Main Difficulties of the Students during the Inquiry Work	Stage
Choice of research topic	1. Difficulty with the choice of a topic that is unfamiliar and new for the students.	2
	2. Difficulty with the choice of topic because of the limited number of possibilities of research topics (from the database of topics)	
	3. Deliberations of the choice of the research topic according to the degree of challenge, interest, and complexity of the topics	2, 3
	4. Difficulty with the focusing of the research topic and prevention of dispersion to other investigation directions	3
Using technological aids and a computerized laboratory	1. Difficulty with the implementation of different technological tools and with a computerized laboratory (such as sensors, computer software), which derives from the lack of knowledge / experience in the use of these tools 2. Coping with lack of accuracy and sensitivity of the technological measurement devices	2
Building a theoretical model	1. Difficulty with the building of a theoretical model, mainly through computerized modeling, because of both the need for mastery of the theoretical background and physical principles of the researched phenomenon and the need for high mathematical knowledge relevant to the research and the mastery of a new programming language	2, 3
Self-regulation: Difficulties with planning & organizing	1. Difficulty with organizing the inquiry work, because of the large and extensive scope required to carry out an inquiry project in this program, in terms of both the learning materials of the research topic and the many research performances done in the project	2

the inquiry work	2. Difficulty taking great personal responsibility of the student for the management and organization of the inquiry work, which requires discipline and self-management	3
Self-regulation: Meeting the time schedule	3. Difficulty meeting the time schedule, because of the great load in this period in the students' lives, from additional commitments other than the program's inquiry work and because of the load of assignments in the inquiry work to advance in the project and because of unexpected problems that appeared during the work	2, 3
Self-regulation: In dealing with situations of uncertainty	4. Difficulty with making an intelligent decision in situations of "no way out" (in the students' view) or situations of uncertainty, such as: <ul style="list-style-type: none"> - Exhausting the investigation in the middle of the process and not knowing about the continuation of the investigation direction - Reaching a situation of lack of satisfaction from the research that was done and/or lack of confidence in the quality of the research - Reaching a situation of dispersion in the inquiry work and/or lack of organization and no guideline throughout the entire work 5. Coping with many frustrations and a feeling of powerlessness when reaching situations of uncertainty	2, 3
Teamwork with the project partner	1. Difficulty with the coordination of times among team members 2. Difficulty with planning the division of the inquiry work and roles in the team, so it will be fair and accepted by the team members	3
Teamwork with peers in the broader group	1. Lack of satisfaction with the sparse social interaction with the other peers in the broader group in the program 2. Lack of satisfaction with the low number of activities that include peer assessment	3

According to the findings, the observations of the student teams and the conversations with the program designers, recommendations were formed for each inquiry component separately (see in chapter 3.4 – Summary of the Findings for the First Research Question), which for the most part are commensurate with the students' reports on the ways of coping with the difficulties they encountered throughout the inquiry work that were presented in the chapter (see 3.1.1, 3.1.2, 3.1.3 in each inquiry component separately in the different stages of the program).

This chapter, part A of the first research question, addressed the students' perception of their experience and their challenge in the performance of inquiry components in the different stages of the inquiry work. Alongside this, the students reported their main aspects of development in these inquiry components, which differed throughout the inquiry work. Hence, the next chapter, part B of the first research question, will address the students' perception of their development in the different inquiry components in the different stages of the inquiry work (in the same stages we addressed in this chapter: the stage of preparation for the inquiry project, the intermediate stage, and the final stage of the inquiry work).

3.2 Findings for Part B of the First Research Question: The Students' Perception of Their Development in the Different Inquiry Components

This sub-chapter presents the findings²³ in response to the following research questions:

- B) Students' perception of their **development** in each stage of the program:
- To what extent did students develop in each of the inquiry components?
 - What aspects of the inquiry components do student believe that they have developed and what are the causes for this development?

This chapter describes a quantitative analysis of the distribution of the students' responses about their development, with reference to different components in the inquiry work and qualitative analysis of the main points of their answers. The first three sections describe the findings at three different points in time in the program: the preparation stage, the intermediate stage, and the final stage of the inquiry work. The last section presents comparisons between the different stages, summary, and an overall picture (quantitative analysis) of the students' perception of their development in the inquiry components throughout the inquiry work.

The components of inquiry are a bit different between stage 1 (the preparation stage) and the two stages, stage 2 (the intermediate stage of the inquiry work) and stage 3 (the final stage of the inquiry project), because of the structure of the activity. In the preparation stage, the students engage in relatively short activities, in which there is analysis of the inquiry, the students experience limited inquiry activities that last between a week and a month (which emphasize each time a specific practice/research instrument). In the second and third stages, the students already engage in the annual project, a long-term inquiry project that lasts about a year and a half. In the two stages, the second and third stages, the students experienced all the inquiry components of the first stage: phrasing questions/goals, planning an experiment, performing an experiment, data processing, drawing conclusions, written reporting on the inquiry, and oral reporting on the inquiry.

²³ From quantitative & qualitative instruments: Preliminary questionnaire (N=33), Inquiry skills questionnaire (N=27), Summative questionnaire (first N=33, second N=34)

However, some of the components were broadened because of the significant time dedicated to them in the annual project relative to the mini-project in the preparation stage and components were added to the second stage and the third stage, which were required in the large annual project but in the preparation stage: choosing a topic, locating information sources, using technological aids and a computerized laboratory, building content knowledge, building a theoretical model, self-regulation, teamwork with the partner, and teamwork with peers in the broader group (the reasons are detailed in the preface of chapter 3).

3.2.1 Stage 1: Preparation Stage of the Inquiry Project – Development in the Inquiry Components (Self-Reporting Questionnaire before the Submission of the “Mini-Project” Report, 10th Grade)

This section presents the quantitative and qualitative analysis of the students’ reporting on the **development** in the different inquiry components in the stage of the preparation of the inquiry project and description of the development aspects in all the inquiry components, from the Inquiry Skills Questionnaire (see appendix number 1.2). The questionnaire was carried out before the submission of the mini-project in the second half of the tenth grade (May 2017), N=27, when there is no teacher-mentor for each team of students but rather two program teacher-mentors providing support and accompaniment for all the teams.

3.2.1.1 Quantitative Analysis – Degree of Development in the Performance of the Inquiry Components (Stag 1 – 10th Grade)

The following figure represents the students’ reporting on the considerable development in the different inquiry components in the second half of the tenth grade- before the submission of the mini-project report (from the Inquiry Skills Questionnaire). In the questionnaire, the students (N=27) were asked to choose at least two inquiry components in which in their opinion they developed considerably during the inquiry work.

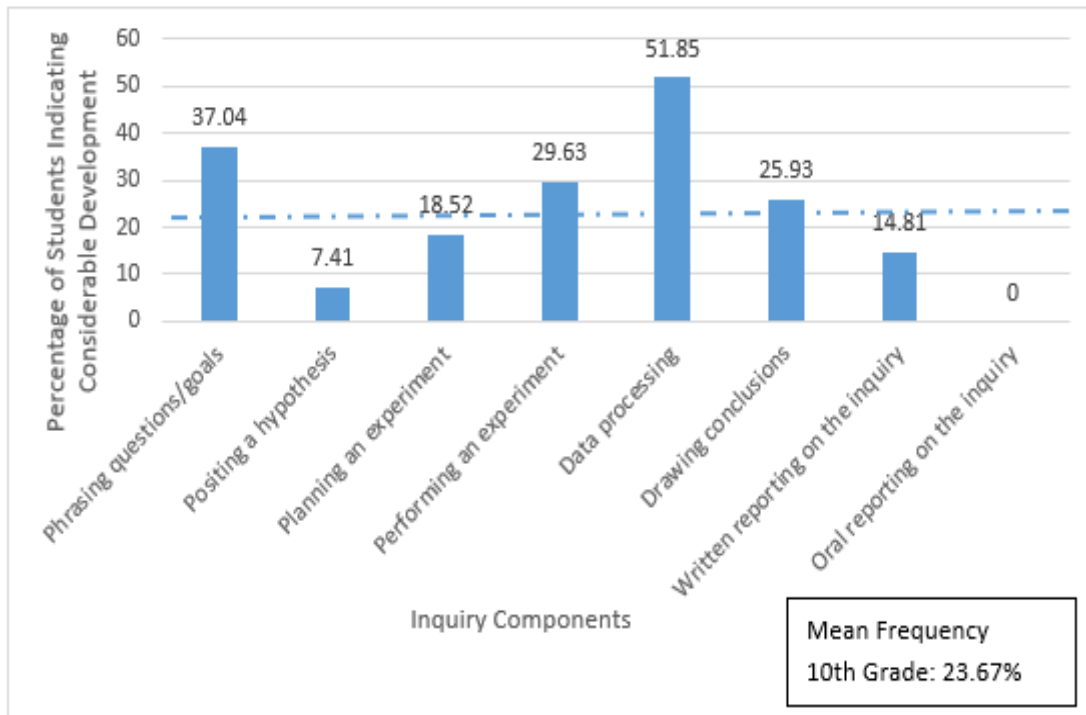


Figure 23: Report of Students on **Considerable Development** in the Different Inquiry Components in the **Preparation Stage** of the Inquiry Project (10th Grade, N=27)

It is possible to see from the bar chart that:

- The inquiry components in which many students (above the mean frequency) reported that they developed considerably are phrasing questions/goals, performing an experiment, data processing, and drawing conclusions. An especially high percentage indicated the inquiry components data processing and phrasing goals/questions.
- The inquiry components in which there are few students (below the mean frequency) reported that they developed considerably are positing a hypothesis, planning an experiment, written reporting on the inquiry, and oral reporting on the inquiry. An especially low percentage indicated the inquiry components of positing a hypothesis and oral reporting on the inquiry.

3.2.1.2 Qualitative Analysis – Detailed Description of Aspects of the Students’ Development in Each Inquiry Component (Stag 1 – 10th Grade)

The following section presents a qualitative analysis of the students’ reports on their development (Appendix 3.2.1 is shown examples of student citations) in the different inquiry components when they work on the min-project in the second half of the 10th grade (from the Inquiry Skills Questionnaire), N=27. In this part, the description of the aspects of developments in the different inquiry components arose from the students’ responses to the questions: “Choose from the above list of skills at least two skills that greatly developed in you during the inquiry work. Give examples that show this development.”

Inquiry Component: Phrasing Questions/Goals

More than one-third of the students (37.04%) reported that they developed greatly in the component of phrasing questions/goals. The students identify that they developed in the component of phrasing questions/goals in the following aspect (Appendix 3.2.1 presents examples of student citations that illustrate this aspect):

1. Phrasing an inquiry question, knowing the structure of the inquiry questions, which is composed of dependence on two physical sizes.

The students attribute the development to the following factors:

1. Considerable experience in the component of phrasing questions/goals in the program.

Inquiry component: Positing a Hypothesis

Less than one-tenth (7.41%) addressed the component of positing a hypothesis as a component that developed greatly. The students identify that they developed in the component of positing a hypothesis in the following aspects (Appendix 3.2.1 presents examples of student citations that illustrate these aspects):

1. Knowing that the component of positing a hypothesis is a part of the inquiry process.
2. Development of creative thinking in positing a hypothesis.

The students attribute the development to the following factors:

1. The possibility to give a place in the inquiry process to the positing of hypotheses on the part of the teacher-mentors, even if the hypotheses are mistaken.

Inquiry Component: Planning an Experiment

About one-fifth of the students (18.52%) report that the development is largely in the component of planning an experiment. The students identify that they developed in the

component of planning an experiment in the following aspects (Appendix 3.2.1 presents examples of student citations that illustrate these aspects):

1. Choosing an appropriate way of investigation independently, through the differentiation between what is important and what is less important during the planning.
2. Awareness of the importance of the component of planning an experiment, which enables more orderly and organized work throughout the entire inquiry process.

Inquiry Component: Performing an Experiment

About one-third of the students (29.63%) report that they developed greatly in the component of performing an experiment. The students identify that they developed in the component of performing an experiment in the following aspects:

1. Improvement of observations on the researched phenomenon.
2. Performance of more complex experiments, which were not tried in the past.

The students attribute the development to the following factors:

1. Considerable experience in the component of performing an experiment in the program.

Inquiry Component: Data Processing

About one-half of the students (51.85%) report that they developed greatly in the component of data processing. The students identify that they developed in the component of data processing in the following aspects (Appendix 3.2.1 presents examples of student citations that illustrate these aspects):

1. Familiarity with and accumulation of experience in the use of computer software (like Excel).
2. Representation and graphical understanding.
3. Recognition of the need first to understand the experiment performed and the logic behind it to process the data.

The students attribute the development to the following factors:

1. Considerable experience in the component of data processing in the program.
2. The very coping with the difficulties that arise during the processing of the data and in the acquisition of skills relate to this component.

Inquiry Component: Drawing Conclusions

About one-quarter of the students (25.93%) report that they developed greatly in the component of drawing conclusions. The students identify that they developed in the

component of drawing conclusions in the following aspects (Appendix 3.2.1 presents examples of student citations that illustrate these aspects):

1. Finding a relationship between two variables of the experiment and additional conclusions from the graph.
2. Development of thinking, especially creative thinking and critical thinking in the process of drawing conclusions.

Inquiry Component: Written Reporting on the Inquiry

About one-seventh of the students (14.81%) report that they developed greatly in the component of written reporting on the inquiry. The students identify that they developed in the component of written reporting on the inquiry in the following aspects (Appendix 3.2.1 presents examples of student citations that illustrate these aspects):

1. Familiarity with the correct structure of an experiment report and accumulation of experience in writing laboratory reports.
2. Familiarity and use of the Word program.

The students attribute the development to the following factors:

1. Experience in the component of written reporting on the inquiry in the program.
2. Providing feedback from the teacher-mentors for students on their written work, which directed them to better writing.

Inquiry Component: Oral Reporting on the Inquiry

The students did not address at all the development in this component

3.2.2 Stage 2: Intermediate Stage of the Inquiry Project – Development in the Inquiry Components (Self-Reporting Questionnaire before the Submission of the Intermediate Report, 11th Grade)

This section presents a quantitative and qualitative analysis of the students' reports on the **development** in the different inquiry components in the intermediate stage of the inquiry project and description of the development aspects in each inquiry component, from the Summative Questionnaire (see Appendix Number 1.4). The questionnaire was held before the submission of the intermediate report of the project, in the second half of the eleventh grade (April, 2018), N=33, when there is a teacher-mentor for each research team.

3.2.2.1 Quantitative Analysis – Degree of Development in the Performance of the Inquiry Components (Stag 2 – 11th Grade)

The following figure represents the students’ reporting on the considerable development in the different inquiry components in the second half of the eleventh grade- after the students’ presentation of the inquiry project and before the submission of the intermediate report (from the Summative Questionnaire). In the questionnaire, the students (N=33) were asked to choose inquiry components (at least two components) in which in their opinion they developed considerably during the inquiry work.

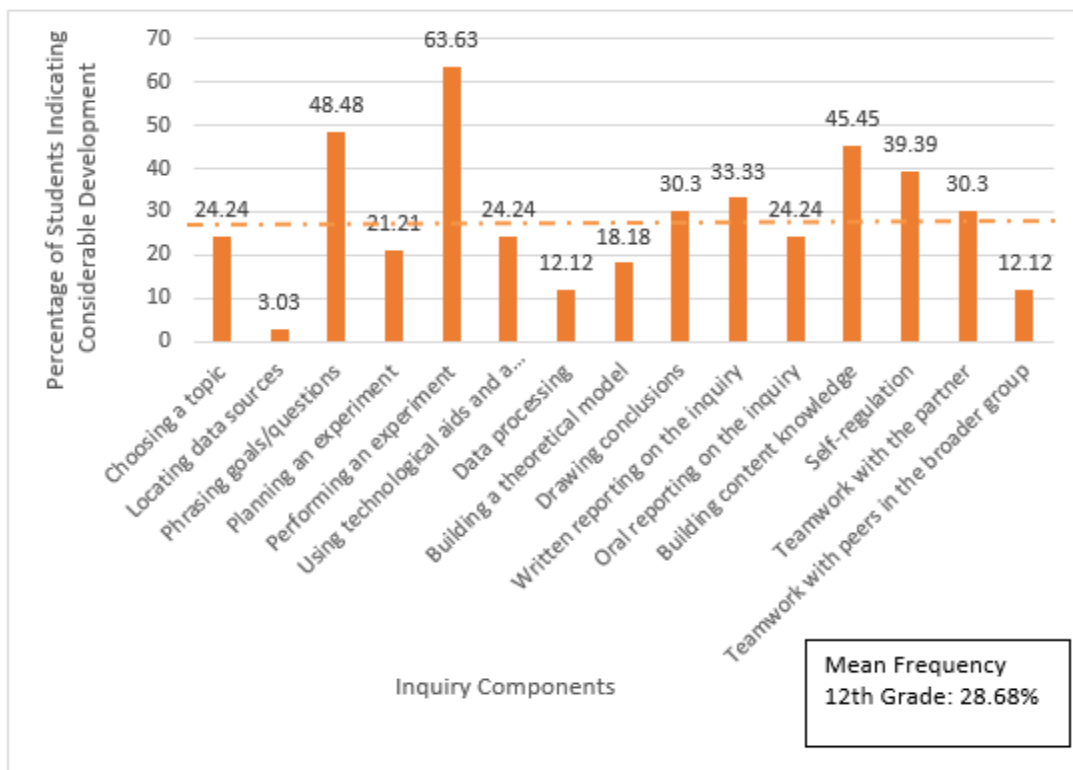


Figure 24: Report of Students on **Considerable Development** in the Different Inquiry Components in the **Intermediate Stage** of the Inquiry Project (11th Grade, N=33)

It is possible to see from the above bar chart that:

- The inquiry components in which many students (above the mean frequency) reported that they developed considerably are phrasing goals and questions, performing an experiment, written reporting on the inquiry, building content knowledge, and self-regulation (when drawing conclusions and teamwork with the

partner are found on the border of the mean of the frequencies). An especially high percentage indicated the inquiry components of performing an experiment, phrasing questions/goals, and building content knowledge.

- Inquiry components in which few students (below the mean frequency) reported that they developed considerably are choosing a topic, identifying information sources, planning an experiment, using technological aids and a computerized laboratory, data processing, building a theoretical model, oral reporting on the inquiry, and teamwork with the peers in the broader group. An especially low percentage indicated the inquiry components of locating information sources and data processing.

3.2.2.2 Qualitative Analysis – Detailed Description of Aspects of the Students’ Development in Each Inquiry Component (Stag 2 – 11th Grade)

The following section presents a qualitative analysis of the students’ reports on their development (Appendix 3.2.2 is shown examples of student citations) in the different inquiry components. The questionnaire was held before the submission of the intermediate report of the project, in the second half of the eleventh grade (from the Summative Questionnaire), N=33. In this part, the description of the development aspects in the inquiry components arose from the students’ responses to question: “Choose from the above list two-three components that you think developed greatly during the program. Describe how you developed in these aspects.” And question: “Tell about the changes (at least two) that you performed during the research work, describe what caused the change and what you learned from it.” The description of the students’ awareness of the things that it is important to them to preserve in the different inquiry components also arose from the responses to the following questions: “Give a ‘tip’ / lesson that you learned for a student beginning in this program” and question: “Note two-three strengths of the program that it is important to preserve.”

Inquiry Component: Choosing an Inquiry Topic

About one-quarter (24.24%) of the students report considerable development in the component of choosing an inquiry topic. The students identify that they developed in the component of choosing an inquiry topic in the following aspects (Appendix 3.2.2 presents examples of student citations that illustrate these aspects):

1. Recognizing and coping dynamically with the inquiry topic and investigation directions.
2. Focusing the inquiry topic.
3. Awareness of the importance of choosing an inquiry topic that interests the learner and was chosen by him.
4. Recognizing that the choice of the topic is not obvious, it is necessary to use judgment.

Students attribute the development to the following factors:

1. Giving the option to students to choose freely the inquiry topic (even if this is from a selection of topics).

Inquiry Component: Phrasing Questions/Goals

About one-half of the students (48.48%) chose the component of asking questions/goals as a component that developed greatly in the program. The students identify that they developed in the component of asking questions/goals in the following aspects (Appendix 3.2.2 presents examples of student citations that illustrate these aspects):

1. Recognizing and coping with the dynamism of the inquiry question.
2. Focusing the inquiry question and avoiding dispersion to a wide range of directions.
3. Awareness of the importance of choosing a sufficiently interesting and open question to reach an in-depth inquiry.
4. Improving the phrasing of the inquiry question compared to the past, which seeks dependence between two variables.

Inquiry Component: Locating Information Sources

Very few students (3.03%) addressed the development in the component of locating information sources relevant to the researched topic. The students identify that they developed in the component of locating information sources in the following aspect (Appendix 3.2.2 presents examples of student citations that illustrate this aspect):

1. Improvement in the technique of the search for information sources in the Internet.

Inquiry Component: Planning an Experiment

About one-fifth of the students (21.21%) reported that they developed greatly in the component of planning an experiment. The students identify that they developed in the component of planning an experiment in the following aspects (Appendix 3.2.2 presents examples of student citations that illustrate these aspects):

1. The level of planning rose, to detailed planning that includes identification and isolation of variables.
2. The recognition that the planning of the experiment is a dynamic process in the inquiry work and changes according to the need.
3. Awareness of the importance of planning independently (without preliminary briefing).

Students attribute the development to the following factors:

1. Giving the possibility to the students in the program to perform the component of planning an experiment independently (unlike the school, which generally bring them an experiment briefing planned ahead of time).

Inquiry Component: Performing an Experiment

About two-thirds of the students (63.63%) report that they developed greatly in the component of performing experiments. The students identify that they developed in the component of performing an experiment in the following aspects (Appendix 3.2.2 presents examples of student citations that illustrate these aspects):

1. Building a better and more effective experiment system, which enables isolation of variables, accuracy in measurements, and minimization of the factors of error as much as possible.
2. Awareness of the importance of the accuracy of measurement during the performance of the experiment.
3. The duration of the time of the building of the system and the time of the performing of the experiment shortened.
4. Recognition that the performance of the experiment is a dynamic and changing performance during the inquiry work.
5. Creative thinking and activity so as to overcome the difficulties that arose during the performance of the experiment.
6. Awareness of the importance of holding initial experiments to understand the phenomenon, to build the knowledge, and to specialize in basic inquiry practices.
7. Awareness of the importance of performing experiments independently.

Students attribute the development to the following factors:

1. Giving the possibility in the program to perform experiments independently.

Inquiry Component: Using Technological Aids and a Computerized Laboratory

About one-quarter of the students (24.24%) report considerable development in the component of using technological aids and a computerized laboratory during the performance of the experiment.

The students identify that they developed in the component of using technological aids and a computerized laboratory in the following aspects (Appendix 3.2.2 presents examples of student citations that illustrate these aspects):

1. Knowing and using new technological aids and a computerized laboratory that they did not know beforehand.
2. Awareness of the importance of the use of technological tools and a computerized laboratory that enables greater depth and breadth of horizons on the investigated phenomenon.

Students attribute the development to the following factors:

1. Accessibility for the students to technological instruments and a computerized laboratory.

Inquiry Component: Data Processing

About one-tenth of the students (12.12%) reported that they developed greatly in the component of data processing. The students identify that they developed in the component of data processing in the following aspects (Appendix 3.2.2 presents examples of student citations that illustrate these aspects):

1. Ability to process data into graphical representation.
2. Awareness of the importance of data processing in a consistent and continuous manner after every experiment.
3. Ability to calculate the value of the error.

Inquiry Component: Drawing Conclusions

More than one-quarter of the students (27.27%) report that they developed greatly in the component of drawing conclusions. The students identify that they developed in the component of drawing conclusions in the following aspects (Appendix 3.2.2 presents examples of student citations that illustrate these aspects):

1. Good ability of drawing conclusions from comparison between the theory and the experiment findings, use of critical thinking and examination of the gaps between

the theory and the experiment findings, and giving explanations for these discrepancies.

2. Understanding that when the experiment results are not commensurate with the theory they are not necessarily mistaken results, but it is possible that they are true and correct results.
3. Good ability of drawing conclusions from comparison between the experiment findings and the findings of the computational modeling.
4. Recognition that the component of drawing conclusions is a dynamic process in the inquiry work and the conclusions can change following the continuation of the inquiry on the phenomenon.

The students attribute the development to the following factors:

1. The very dealing with the comparison between the theory and the experiment findings (primarily when the results are not commensurate with the theory and they are required to provide explanations why)
2. Use of computational modeling, with which it was possible to compare between it and the experiment findings and to reach conclusions (especially when the students did not succeed in solving equations analytically).

Inquiry Component: Written Reporting on the Inquiry

One-third of the students (33.33%) report that there is considerable development in the component of written reporting on the inquiry. The students identify that they developed in the component of written reporting on the inquiry in the following aspects (Appendix 3.2.2 presents examples of student citations that illustrate these aspects):

1. Improvement in documenting the inquiry process in the research journal, to more ordered, consistent, and flowing documentation during the inquiry work.
2. Awareness of the importance of documenting the inquiry.
3. Improvement in the writing of experiment reports and writing of the summative work, to more detailed writing that includes all the parts of the structure of an experiment report and structure of a scientific work.
4. Improvement in the writing of presentations, to organized, concise writing (in which there are the main points) that is clear to the audience.

Students attribute the development to the following factors:

1. Encouragement of the teacher-mentors to write in the work journal on Google Drive.
2. Awareness of the importance of the documenting of the inquiry process.

Inquiry Component: Oral Reporting on the Inquiry

About one-quarter of the students (24.24%) report that they developed greatly in the component of oral reporting on the inquiry. The students identify that they developed in the component of oral reporting on the inquiry in the following aspects (Appendix 3.2.2 presents examples of student citations that illustrate these aspects):

1. Overcoming the fear/shyness/pressure in the presentation in front of the audience more than in the past.
2. Improvement in the oral performance of the presentation, both in the content of the presentation (presentation of the main things in the allotted time) and in the improvement in standing in front of the audience (rise in the self-confidence that includes body language and improvement in speaking clearly and in a way understood by the audience).

Students attribute the development of the following factors:

1. Preparations for every presentation orally, before peers and relatives.
2. Repeated attempts of oral presentation in front of an audience in the program and drawing lessons from previous presentations.

Inquiry Component: Building Content Knowledge

Nearly one-half of the students (45.45%) reported that they developed greatly in the component of building content knowledge. The students identify that they developed in the component of building content knowledge in the following aspects (Appendix 3.2.2 presents examples of student citations that illustrate these aspects):

1. In-depth and in-breadth understanding of the physical knowledge related to the researched phenomenon (for the most part contents from outside of the high school curriculum).
2. Awareness of the importance of building content knowledge to prepare a program of experiments and advance the inquiry.
3. Ability to develop formula that link between physical sizes independently.
4. Improvement of the independent learning ability in different topics.

5. Quicker absorption of knowledge, understanding, and implementation of the knowledge acquired than in the past.
6. Awareness of the importance of taking responsibility for their learning and need to invest to build the content knowledge.
7. Recognition of the fact that there is a need for openness for learning new things, increasing curiosity and self-challenge in building content knowledge.

Students attribute the development to the following factors:

1. Giving the possibility in the program to learn about diverse contents beyond the curriculum and the way in which they are learned in the inquiry method and independently.
2. Character traits such as natural curiosity, self-challenging, openness to new things, motivation, and desire to succeed, investment, perseverance, seriousness, and responsibility for learning.
3. Help and support on the part of the teacher-mentors when they encountered difficulties in building content knowledge.

Inquiry Component: Building a Theoretical Model

Nearly one-fifth of the students (18.18%) report that they developed greatly in the component of building a theoretical model. The students identify that they developed in the component of building a theoretical model in the following aspects (Appendix 3.2.2 presents examples of student citations that illustrate these aspects):

1. Recognition and use of computational modeling for the purpose of building a theoretical model they didn't know about beforehand.
2. Awareness of the importance of the engagement in the building of a theoretical model for the deeper understanding of the physical concepts and principles related to the investigated phenomenon.

Students attribute the development to the following factors:

1. Learning in the "Computational Modeling" course before the beginning of the work on the inquiry project, in which the students learned about another instrument for investigation and for building a theoretical model for the investigated phenomenon.

Inquiry Component: Self-Regulation

Nearly 40% of the students (39.39%) report that they developed greatly in the practices related to self-regulation in the context of management of the inquiry work. The students primarily addressed the development of practices such as planning and organization of the inquiry work, meeting the time schedule, and coping with situations of uncertainty. The first practice that was prominent among the students is the practice of the planning and organizing of the inquiry work. Nearly two-third of the students who described the development of the practices associated with self-regulation chose this practice. About one-half of the students (from the students who reported the maximal development in self-regulation) describe development related to the practice of meeting the time schedule. More than one-third of the students (of the students who reported considerable development in self-regulation) describe development related to coping with situations of uncertainty during the inquiry process.

The students identify that they developed in the component of self-regulation in the context of the management of the inquiry work in the following aspects (Appendix 3.2.2 presents examples of student citations that illustrate these aspects):

Improvement in planning and organizing the inquiry work:

1. Planning the inquiry work in a more organized and effective manner than in the past.
2. Awareness of the importance of the planning and organization of the research work.
3. Improvement in the management of the inquiry work independently and taking more personal responsibility for the advancement of the inquiry and the nature of the inquiry.

Improvement in meeting the time schedule:

4. Improvement in the time schedule through the correct and orderly planning of the time between the work on the inquiry project and the learning for tests and other commitments of the school.
5. Awareness of the importance of time planning and meeting the time schedule.

Improvement in dealing with situations of uncertainty:

6. The recognition that situations of uncertainty during the inquiry work are a part of the inquiry process.

7. Stable standing versus situations of uncertainty during the inquiry work more than in the past through the development of ability of perseverance, determination, and development of creative thinking.

Students attribute the development to the following factors:

1. Awareness of the existence of situations of uncertainty in the process of the inquiry work that must be overcome through perseverance and determination.
2. Development of the ability of perseverance and determination.
3. Development of individual and creative thinking and giving a place for its expression in the program.
4. Support of the teacher-mentors (practically and mentally) in a time of situations of uncertainty, which helped them overcome these situations (the teacher-mentors gave them tools for overcoming situations of uncertainty and confidence to continue the inquiry).

Inquiry Component: Teamwork with the Partner in the Project

Nearly one-third of the students (30.30%) report that teamwork with the partner in the project developed greatly during the inquiry work. The students identify that they developed in the component of teamwork with the project partner in the following aspects (Appendix 3.2.2 presents examples of student citations that illustrate these aspects):

1. Performance of the proper division of work between the partners and cooperation of each one of them that led to the improvement in the teamwork and in the work effectiveness.
2. Development of interpersonal skills such as management of a respectful dialogue, giving place to another opinion, and expressing each one in the work, flexibility and compromise on the part of each one of them, openness and trust in the partner.
3. Social responsibility (to identify a situation of distress in the partner and to offer help), with backup and mutual support between the project partners primarily when encountering a certain difficulty or when they need to make a joint decision.
4. Development of in-depth friendship relations with the partner following the close teamwork throughout the inquiry work.
5. Awareness of the importance of good teamwork with the partner in the inquiry work because of its advantages.

Inquiry Component: Teamwork with the Peers in the Broader Group

About one-tenth of the students (12.12%) addressed the component of teamwork with the other peers who are participating in the program. The students identify that they developed in the component of teamwork with the peers in the broader group in the following aspect (Appendix 3.2.2 presents examples of student citations that illustrate this aspect):

1. Development of interpersonal skills of openness and trust between friends, ability to ask help from the friends and giving help when needed.

Inquiry Component: Identifying with the World of Scientific Inquiry

About one-fifth of the students (21.21%) wrote an expression of identification with the scientist's world. The students identify that they developed in the component of identification with the world of scientific inquiry in the following aspect (Appendix 3.2.2 presents examples of student citations that illustrate this aspect):

1. Experience with the scientist's world, in which they learn and research through discovery and inquiry, define a problem, search for and are committed to finding a solution, which is accompanied by curiosity and creativity.

The students attribute the development to the following factors:

1. **Creation of an atmosphere similar to the atmosphere of a scientist in his laboratory** (and different from the atmosphere of the school), which inspires the student's curiosity, encourages inquiry, enables freedom of choice for the teaching methods, allows access to diverse and considerable equipment found in the laboratory, puts emphasis on the practical side of the research and not only the theoretical side, and creates situations that require creative thinking.

3.2.3 Stage 3: Final Stage of the Inquiry Project – Development in the Inquiry Components (Self-Reporting Questionnaire before the Submission of the Summative Report, 12th Grade)

This section presents the quantitative and qualitative analysis of the students' reports on the **development** in the inquiry components in the final stage of the inquiry project and description of aspects of development in each inquiry components, from the Summative Questionnaire (see Appendix Number 1.4). The questionnaire was filled out

before the submission of the summative report of the project, in the second half of the twelfth grade, after the students' presentation of the project (May, 2019), N=34, when there is a teacher-mentor for each research team.

3.2.3.1 Quantitative Analysis – Degree of Development in the Performance of the Inquiry Components (Stag 3 – 12th Grade)

The following figure represents the students' reporting on the considerable development in the different inquiry components in the second half of the twelfth grade- after the students' presentation of the inquiry project and before the submission of the summative report (from the Summative Questionnaire (repeat)). In the questionnaire, the students (N=34) were asked to choose at least two inquiry components in which in their opinion they developed greatly during the inquiry work.

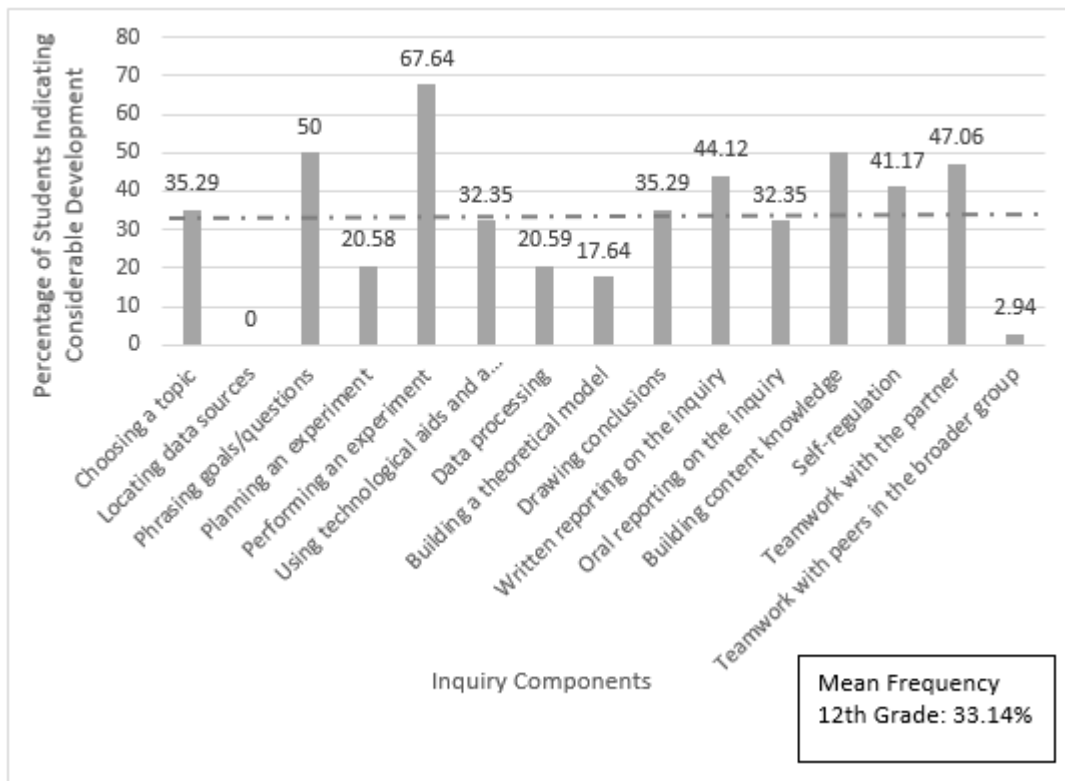


Figure 25: Report of Students on **Considerable Development** in the Different Inquiry Components in the **Final Stage** of the Inquiry Project (12th Grade, N=34)

It is possible to see from the above bar chart:

- The components of inquiry in which many students (above the mean frequency) reported that they developed greatly are choosing the topic, phrasing questions/goals, performing an experiment, using technological aids and a computerized laboratory, drawing conclusions, written reporting on the inquiry, building content knowledge, self-regulation, and teamwork with the partner. An especially high percentage indicated the inquiry components of performing an experiment, phrasing questions/goals, and building content knowledge.
- The inquiry components in which few students (below the mean frequency) reported that they developed considerably in the inquiry components are locating information sources, planning an experiment, data processing, building a theoretical model, oral reporting on the inquiry, and teamwork with the peers in the broader group. An especially low percentage indicated the inquiry components of locating information sources and teamwork with the peers in the broader group.

3.2.3.2 Qualitative Analysis – Detailed Description of the Aspects of the Students’ Development in Each Inquiry Component (Stag 3 – 12th Grade)

The following section presents a qualitative analysis of the students’ reports on their development (Appendix 3.2.3 is shown examples of student citations) in the different inquiry components before the submission of the summative report of the project in the second half of the 12th grade (from the Summative Questionnaire), N=34. In this part, a description of the aspects of development in the inquiry components arose from the students’ answers to question: “Choose from the above list two-three components that you think greatly developed in you during the program. Describe how you developed in these aspects.” and question: “Tell about the changes (at least two) that you performed during the research work. Describe what caused the change and what you learned from it.” The description of the students’ awareness of things it is important to them to preserve in the different inquiry components arose also from the answers to the following questions: question: “Give a ‘tip’ / lesson you learned to a student beginning in this program” and question: “Note two-three strengths of the program that it is important to keep.”

Inquiry Component: Choosing the Inquiry Topic

A little more than one-third of the students (35.29%) report that they developed greatly in the component of choosing a topic and choosing directions of investigation. The students identify that they developed in the component of choosing an inquiry topic in the following aspects (Appendix 3.2.3 presents examples of student citations that illustrate these aspects):

1. Recognizing and coping dynamically with the inquiry topic and investigation directions, which change during the performance of the inquiry.
2. Focusing the topic and investigating it in-depth and avoiding sliding into different topics.
3. Ability to make decisions independently, to choose the inquiry topic, the investigation directions, and ways of investigation.

The students attribute the development to the following factors:

1. Receiving free choice from the teacher-mentors on the different inquiry topics, investigation directions, and investigation method.
2. Receiving a range of possibilities of inquiry topics and ways of investigation.

Inquiry Component: Phrasing Questions/Goals

Half of the students (50%) report that they developed greatly in the component of phrasing questions/goals. The students identify that they developed in the component of phrasing questions/goals in the following aspects (Appendix 3.2.3 presents examples of student citations that illustrate these aspects):

1. Recognition of and coping dynamically with the inquiry question, which changes following developments during the inquiry work.
2. Focusing the inquiry question.
3. Asking questions in the spirit of inquiry, which can develop into quantitative in-depth inquiry.

Inquiry Component: Planning an Experiment

About one-fifth of the students (20.58%) report that they developed considerably in the component of planning an experiment. The students identify that they developed in the component of planning an experiment in the following aspects (Appendix 3.2.3 presents examples of student citations that illustrate these aspects):

1. Identification of variables that influence the phenomenon and the separation of the variables in the planning of the experiment.
2. Development of creativity and initiative so as to improve the planning of the experiment and to overcome the difficulties encountered in the performance of the inquiry.
3. Recognition and coping dynamically with the planning of the experiment.

The students attribute the development to the following factors:

1. The very coping with the dynamism and difficulties that arise during the planning of the experiment.

Inquiry Component: Performing an Experiment

About two-thirds of the students (67.64%) report that they developed greatly in the component of performing an experiment. The students identify that they developed in the component of performing an experiment in the following aspects (Appendix 3.2.3 presents examples of student citations that illustrate these aspects):

1. Ability to improve the experiment system, to minimize the mistakes and achieve more accurate outcomes.
2. Ability to perform an experiment more independently than in the past.
3. Development of the ability to solve problems and to develop from creativity to providing an answer to problems observed in the experiment.
4. Awareness of the importance of improvement of the constellation of the experiment so as to provide a precise and focused response to the inquiry question.
5. Recognition of the dynamism of the experiment performance, that it is necessary to change the system of the experiment according to the directions of investigation that change during the inquiry work.
6. Awareness of the importance of mutual dependence between ownership of the inquiry and enjoyment of the research.

The students attribute the development to the following factors:

1. The very coping with the dynamism and difficulties arising during the building of the system and the performance of the experiment.
2. Enabling independence and initiative of students to overcome the problems observed during the inquiry work.

3. The support of the teacher-mentors and laboratory assistants, who encourage them to succeed and to continue with the inquiry.
4. Access to equipment in the laboratory in the institute, giving considerable equipment, and a broad range for building the different systems.

Inquiry Component: Using Technological Aids and a Computerized Laboratory

About one-third of the students (32.35%) report that they developed greatly in the component of using technological aids and a computerized laboratory. The students identify that they developed in the component of using technological aids and a computerized laboratory in the following aspects (Appendix 3.2.3 presents examples of student citations that illustrate these aspects):

1. Familiarity with the space of technological and computerized tools for investigation and mastering the use of these tools.
2. Deeper learning and inquiry of the researched phenomenon and giving ideas for additional directions of investigation following the experience with the computerized laboratory and technological aids.
3. Awareness of the need and necessity of the use of technological aids and a computerized laboratory in the inquiry process, when the use of these gave them an answer to the difficulties that arose during the performance of the inquiry.
4. Recognition of the advantages of the use of technological aids and a computerized laboratory that significantly makes the investigation method easier and increases the quality of the inquiry.

The students attribute the development to the following factors:

1. The approach of the Davidson Institute laboratory, which enables access to advanced and innovative equipment.

Inquiry Component: Data Processing

About one-fifth of the students (20.59%) report that they developed greatly in the component of data processing. The students identify that they developed in the component of data processing in the following aspects (Appendix 3.2.3 presents examples of student citations that illustrate these aspects):

1. Specialization in the use of different tools that enable data processing in a professional manner.

2. Evaluation of the range of uncertainty of the measurement and its comparison to the range of mistake of the experiment that leads to critical thinking (In other words, also development of critical thinking following the engagement in the data processing)

The students attribute the development to the following factors:

1. Many experiences with the software program for data processing during all the years in the inquiry work.

Inquiry Component: Drawing Conclusions

A little more than one-third of the students (35.29%) reported that they developed greatly in the component of drawing conclusions. The students identify that they developed in the component of drawing conclusions in the following aspects (Appendix 3.2.3 presents examples of student citations that illustrate these aspects):

1. Ability to find a relationship between two variables that were measured in an experiment and describe in a conclusion the type of relationship.
2. Ability of comparison and linkage between the experiment findings and the theory and/or computational modeling to reach more focused conclusions.
3. Recognition and coping dynamically with drawing conclusions, which can change following the development in the inquiry.
4. Focusing of the conclusions, through control, examination, discussion of them, and filtering of some of the conclusions, when their correctness was doubted.
5. Understanding that when the experiment results do not suit the theory they are not necessarily mistaken results but it is likely that they are real and true results.

Inquiry Component: Written Reporting on the Inquiry

Nearly one-half of the students (44.12%) report that they developed greatly in the component of written reporting on the inquiry. The students identify that they developed in the component of written reporting on the inquiry in the following aspects:

1. Improvement of the ability to document the inquiry process, which is expressed in the meticulous and ongoing documenting during the inquiry more than in the past and detailed documenting in the work journal.
2. Awareness of the importance of documenting of the inquiry process and its advantages.

3. Improvement in the level of the writing, in the phrasing of the writing, in the correct use of scientific language, and in the organization of all components of the work summarizing the inquiry project.
4. Improvement in the abilities of control differentiation of important and less important points, and making decisions on the writing of the work.
5. Improvement of the skills associated with writing presentations, in terms of the summarization of the main things, better visibility of the contents, agility and the time needed to write them and even enjoy the writing process.

The students attribute the development to the following factors:

1. Peer assessment and feedback from teacher-mentors and peers that provided them with suggestions for the improvement of the writing.

Inquiry Component: Oral Reporting on the Inquiry

About one-third of the students (32.35%) report that they developed greatly in the component of oral reporting on the inquiry. The students identify that they developed in the component of oral reporting on the inquiry in the following aspects (Appendix 3.2.3 presents examples of student citations that illustrate these aspects):

1. Improvement in the ability to present and stand in front of an audience compared to the past.
2. Rise in the feeling of efficacy and self-confidence in giving a presentation in front of an audience and reducing stress and anxiety.

The students attribute the development to the following factors:

1. Experiences of oral reporting of the inquiry in front of an audience during the program as a part of the program requirements.

Inquiry Component: Building Content Knowledge

One-half of the students (50%) report that they developed greatly in the component of building content knowledge. The students identify that they developed in the component of building knowledge content in the following aspects (Appendix 3.2.3 presents examples of student citations that illustrate these aspects):

1. Learning and understanding of the relevant theoretical background to the inquiry and inquiry processes, especially in students who did not have previous knowledge, until the learning of content knowledge in-depth and at a high level.

2. Love and interest in inquiry and physics following the building of content knowledge.
3. Awareness of students of the importance of building content knowledge in the inquiry process, which makes the practical inquiry into more in-depth and meaningful.
4. Development of formulae in an independent manner through experience and theoretical background that is acquired during the inquiry.
5. Acquisition of learning style (different from the school), which integrates practical experience through theoretical learning in the investigation of the phenomenon.
6. Independent learning of the researched phenomenon and ways of investigation.
7. Recognition of the need for openness in learning (to come with an ‘open mind’ and to be curious) of new topics and adjustment ability to new and different learning abilities in the school.

The students attribute the development to the following factors:

1. Openness to learning (to come with an ‘open mind’) of new topics.
2. Awareness of difference between the learning style in the school and the learning style in the research physics program, and therefore there is a need for the ability of adjustment to different and new learning styles, like learning through inquiry and independent learning, combining hands-on experience with theoretical learning.
3. Enabling coping with the difficulties involved in building content knowledge independently
4. Support and help on the part of the teacher-mentors and academic counselors.

Inquiry Component: Building a Theoretical Model

About one-sixth of the students (17.64%) reported that they developed greatly in the component of building a theoretical model. The students identify that they developed in the component of building a theoretical model in the following aspects (Appendix 3.2.3 presents examples of student citations that illustrate these aspects):

1. Familiarity with and experience in building a theoretical model using computational modeling.
2. Awareness of the importance of engagement in building a theoretical model for the more in-depth understanding of the phenomenon and even prediction/discovery of additional phenomena.

3. Development of computer programming language following the building of a theoretical model in a computerized manner.

The students attribute the development to the following factors:

1. The learning in the course of computational modeling before the beginning of the project and from the experience in this component during the inquiry work.

Inquiry Component: Self-Regulation

About forty percent of the students (41.17%) report that they developed greatly in the practices associated with self-regulation in the context of management of the inquiry work. The students addressed primarily the development of practices such as planning and organizing the inquiry work, meeting time schedule, and coping with situations of uncertainty. Nearly 80% (of the students who reported considerable development in self-regulation) describe development associated with practices of planning and organizing an inquiry work. About one half of them describe development associated with practices of meeting a time schedule and about one-third describe development related to coping with situations of uncertainty during the inquiry process.

The students identify that they developed in the component of self-regulation in the context of management of inquiry work in the following aspects (Appendix 3.2.3 presents examples of student citations that illustrate these aspects):

Improvement in the planning and organization of inquiry work:

1. Management of the inquiry work in a more organized and effective manner.
2. Awareness of the importance of planning the inquiry, organization, and management of a work journal.
3. Increase of the work ethic and personal responsibility over the progress of the work and success of the inquiry project.
4. Critical thinking on the performances and process of progress in the inquiry.
5. Taking more initiative and independent work in the management of the inquiry.

Improvement in meeting the time schedule:

6. Improvement in meeting time schedule through planning a better schedule.
7. Awareness of the importance of meeting times in the inquiry process.

Improvement in dealing with situations of uncertainty:

8. Recognition that the situation of failure/frustration is a temporary situation and a situation from which it is possible to develop and grow to additional directions of investigation and to further the depth of the investigation.
9. Awareness of the importance of the development of character traits such as perseverance, determination, not giving up, and optimism, so as to advance in the inquiry, which are needed especially to overcome situations of uncertainty and powerlessness during the inquiry process.
10. Development of creative thinking and awareness of the need for it to overcome situations of uncertainty and powerlessness during the inquiry work.
11. Feeling of ownership and leadership of the students over their inquiry project following the overcoming of situations of uncertainty and powerlessness during the inquiry work.

The students attribute the development to the following factors:

1. Perseverance and determination.
2. Seriousness and taking personal responsibility over the inquiry work until its end.
3. Creative and critical thinking to overcome situations of uncertainty
4. Receiving help and advice from the teacher-mentors, academic counselors, and other people who supported them when they reached uncertainty or powerlessness.

Inquiry Component: Teamwork with the Partner in the Project

About one-half of the students (47.06%) report that they developed greatly in the component of teamwork with the project partner. About one-half of them report in general an improvement in their teamwork ability compared to the past. For example: “I developed in my teamwork ability compared to the past” (student 21, M), “I developed in the teamwork” (student 2, student 4, both M).

The students identify that they developed in the component of teamwork with the project partner in the following aspects (Appendix 3.2.3 presents examples of student citations that illustrate these aspects):

1. Correct division of the roles and work between the partners.
2. Sharing ideas and mutual fertilization with one another.

3. Recognition of the strengths and weaknesses of the partners and consequently the complementing of the partners' weaknesses through the other partner's strengths.
4. Development of interpersonal skills such as showing empathy, consideration, giving space and respect to one another, providing support and backup for the partner.
5. Creation of relations of in-depth friendship.
6. Awareness of the importance of teamwork and its many advantages mentioned above, which lead to effective, quality, and enjoyable work.

Inquiry component: Teamwork with the Peers in the Broader Group

There is almost no reference of the students (2.94%) to the component of teamwork with the peers in the broader group. In addition, few bothered to explain the development in this component. The students identify that they developed in the component of teamwork with the peers in the broader group in the following aspects (Appendix 3.2.3 presents examples of student citations that illustrate these aspects):

1. Awareness of the importance of teamwork with the peers in the broader group, which is another source for receiving constructive criticism, support, help, and encouragement if needed.
2. Creation of a relationship with students from different places in the country.

Inquiry Component: Identifying with the World of Scientific Inquiry

About one-tenth of the students (8.82%) wrote an expression of identification with the scientist's world, some of the students express the desire to be in this world in the future: Recognizing what the world of the researcher / scientists looks like and identifying with the way that the scientist goes through in the inquiry process, which includes also difficult situations he must overcome, simultaneous with the discovery of the beauty of doing inquiry itself and its products (Appendix 3.2.3 presents examples of student citations).

3.2.4 Comparison between the Stages (Preparation, Intermediate, and Final) of the Inquiry Project – Development in the Inquiry Components

This section describes comparisons in the students' development in the different inquiry components in different stages in the program. In each stage, the students were asked to choose at least two inquiry components in which in their opinion they developed greatly during the inquiry work. In the first section, we will address only the inquiry components that

were common to all the questionnaires in the three different points of time: the preparation stage, the intermediate stage, and the final stage of the inquiry work and that constitute a main part of the inquiry process. In the next section we broaden to additional inquiry components that were examined only in the last two stages of the inquiry work (considerations on the addition of the inquiry components in the last two stages are explained at the start of this sub-chapter). The last section provides a summary and an overall picture of the students' perception of their development in the inquiry components throughout the entire inquiry work.

3.2.4.1 Development of Students in the Performance of the Inquiry Components Examined in Three Stages

3.2.4.1.1 Comparison between Stage 1 (Preparation Stage) and Stage 2 (Intermediate Stage) – Development in the Inquiry Components

The following figure represents the students' reporting on the **considerable development** in the different inquiry components – comparison between the preparation stage of the inquiry project (in the second half of the tenth grade, N=27, before the submission of the mini-project report, from the Inquiry Skills Questionnaire) and the intermediate stage (in the second half of the eleventh grade, N=33, before the submission of the intermediate project report. from the Summative Questionnaire).

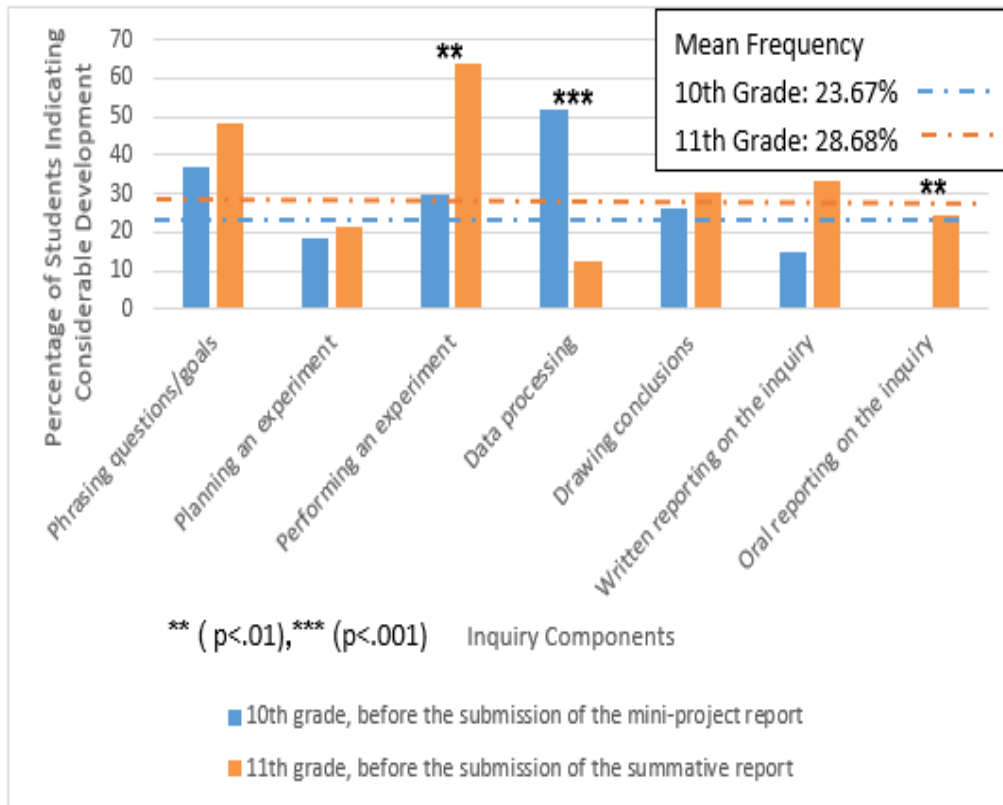


Figure 26: Report of Students on **Considerable Development** in the Inquiry Components – Comparison between the Preparation Stage (N=27) and the Intermediate Stage (N=33) of the Inquiry Project

The above bar chart found that there is a significant difference, $\chi^2=58.6(14)$: $p<.001$, between the preparation stage and the intermediate stage in the percentage of the students who indicate the considerable development of the inquiry components presented in the figure, as follows:

- It was found that there is a significant increase ($p<.01$) in the components of performing an experiment and oral reporting on the inquiry.
 - In the component of performing an experiment, in addition to the significant increase, both in the stage of preparation and in the intermediate stage, many students (above the mean frequency) reported considerable development.
 - In the component of oral reporting on the inquiry, while there is a significant increase, in the preparation stage and the intermediate stage few students (below the mean frequency) report considerable development.

- A significant change ($p > .05$) was not found in the components of phrasing questions/goals, planning an experiment, drawing conclusions, and written reporting on the inquiry.
 - In the components of phrasing questions/goals and drawing conclusions both in the preparation stage and in the intermediate stage many students (above the mean frequency) reported considerable development.
 - In the component of planning an experiment both in the preparation stage and in the intermediate stage few students (below the mean frequency) report considerable development.
 - In the component of written reporting on the inquiry, although there is no significant change, while in the preparation stage few students (below the mean frequency) report considerable development in the intermediate stage many students (above the mean frequency) report this and a trend of increase can be seen.
- It was found that there is a significant decrease ($p < .001$) in the component of data processing.
 - In the component of data processing while in the preparation stage many students (above the mean frequency) report considerable development in the intermediate stage few students (below the mean frequency) report this.

3.2.4.1.2 Development in the Inquiry Components – Comparison between Stage 2 (Intermediate Stage) and Stage 3 (Final Stage)

The following figure represents the students' report on the **considerable development** in the different inquiry components – comparison between the intermediate stage (in the second half of the eleventh grade, $N=33$, before the submission of the intermediate report of the project, from the Summative Questionnaire) and the final stage (in the second half of the twelfth grade, $N=34$, before the submission of the summative report, from the Summative Questionnaire (repeat)).

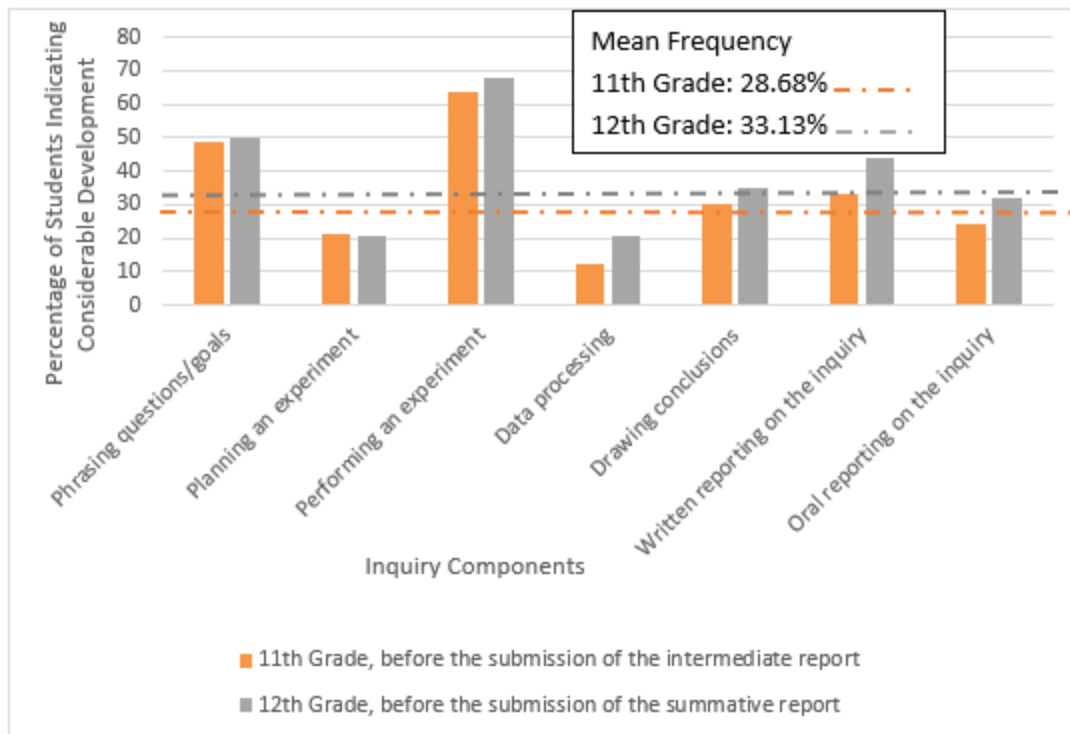


Figure 27: Report of Students on **Considerable Development** in the Inquiry Components – Comparison between the Intermediate Stage (N=33) and the Final Stage (N=34) of the Inquiry Project

The above bar chart found that there is no significant difference between the intermediate stage and the final stage in the inquiry project in the percentage of the students who indicate the considerable development of the inquiry components presented in the figure, as follows:

- A significant difference was not found ($p > .05$) in all the inquiry components presented in the above figure.
 - In the components of phrasing questions/goals, performing an experiment, drawing conclusions, and written reporting on the research both in the intermediate stage and in the final stage many students (above the mean frequency) reported considerable development.
 - In the components of planning an experiment and data processing, both in the intermediate stage and in the final stage few students (below the mean frequency) report considerable development.

- In the component of oral reporting on the inquiry, although there is no significant change, while in the intermediate stage few students (below the mean frequency) report considerable development, in the final stage the percentage of students who report this is almost equal to the mean frequency and the trend of increase can be seen.

3.2.4.2 Development of Students in the Performance of Additional Inquiry Components Examined in the Last Two Stages

3.2.4.2.1 Comparison between Stage 2 (Intermediate Stage) and Stage 3 (Final Stage) – Development of in Additional Inquiry Components

The following figure represents the students' reporting on **considerable development** in eight **additional inquiry components**: between the intermediate stage of the inquiry project (in the second half of the eleventh grade, N=33, before the submission of the intermediate report of the project, from the Summative Questionnaire) and the final stage of the inquiry project (in the second half of the twelfth grade, N=34, before the submission of the summative report, from the Summative Questionnaire (repeat)).

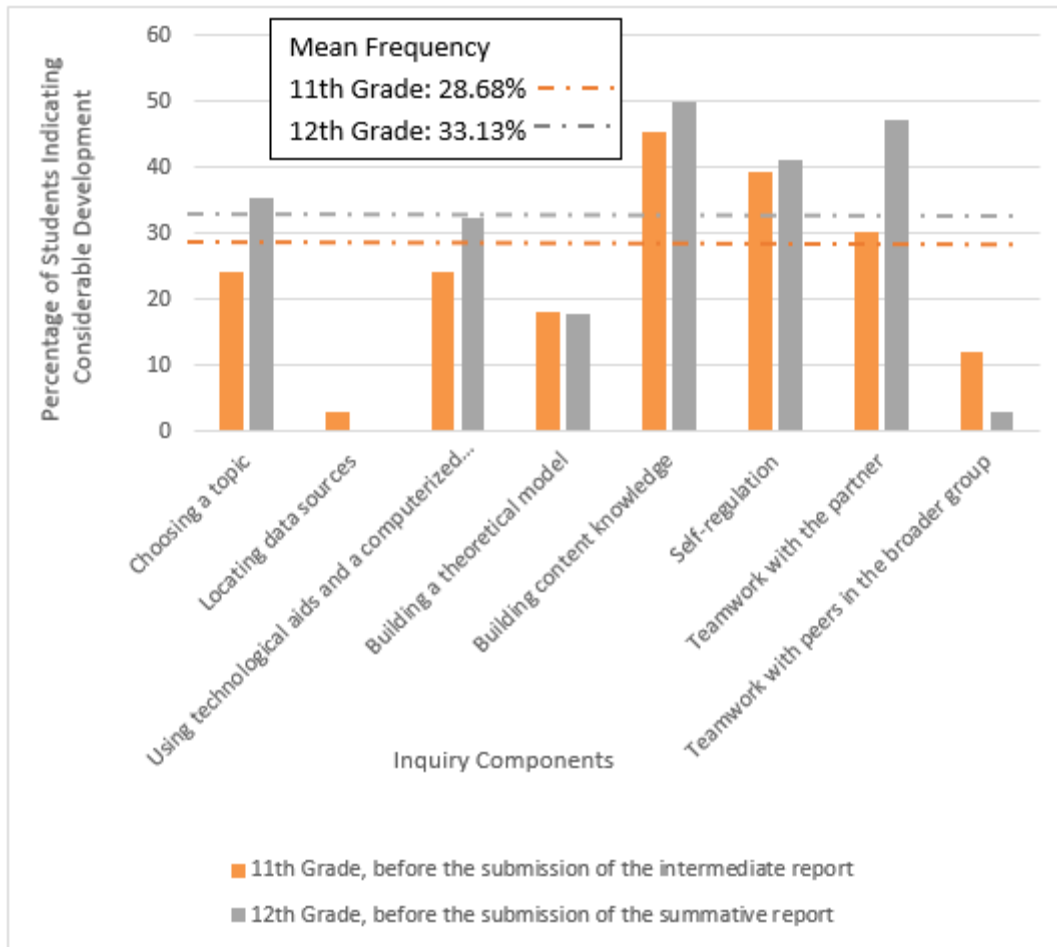


Figure 28: Report of Students on **Considerable Development** in the **Additional** Inquiry Components – Comparison between the Intermediate Stage (N=33) and the Final Stage (N=34) of the Inquiry Project

In the above bar chart, it was found that there is no significant difference ($p > .05$) between the intermediate stage and the final stage in the inquiry project in the percentage of students who indicate considerable development in all the inquiry components presented in the figure.

- A significant difference was not found ($p > .05$) in all the inquiry components presented in the above figure.
 - In the components of building content knowledge, self-regulation, and teamwork with the partner, in both the intermediate stage and in the final stage many students (above the mean frequency) reported considerable development.

- In the components of locating information sources, building a theoretical model, and teamwork with peers in the broader group, in both the intermediate stage and in the final stage few students (below the mean frequency) report considerable development.
- In the component of choosing a topic, although there is no significant change, while in the intermediate stage few students (below the mean frequency) report considerable development, in the final stage many students (above the mean frequency) report this and a trend of increase can be seen.
- In the component of using technological aids and a computerized laboratory, although there is no significant change, while in the intermediate stage few students (below the mean frequency) reported considerable development, in the final stage of the project the percentage of students who report this is almost equal to the mean frequency (33.13%) and a trend of increase can be seen.

3.2.5 Main Findings – Students’ Perception of Their Development in the Performance of the Inquiry Components in the Different Stages in the Program

3.2.5.1 Main Findings of the Quantitative Analysis – The Students’ Perception of the Degree of Their Development in the Performance of Inquiry Components in the Different Inquiry Stages

3.2.5.1.1 Students’ Perception of the Degree of Their Development in the Performance of the Inquiry Components Examined in the Three Stages

This subchapter presents the main findings of the percentage of students who indicate considerable development in the different inquiry components relative to the mean frequency and with emphasis on the significant changes between the stages, especially between the preparation stage and the final stage. To see the overall picture of the students’ degree of development in the performance of the inquiry components examined in the three stages, we will look at the following figures.

The first of the following figures represents the overall picture of the **students' reporting on their development in the performance of the inquiry components** in the different inquiry components in the different stages of the program: the preparation stage of the inquiry project (in the second half of the 10th grade, N=27, before the submission of the mini-project), the intermediate stage (in the second half of the 11th grade, N=33, before the submission of the project intermediate report), and the final stage (in the second half of the 12th grade, N=34, before the submission of the summative report). It is possible to see in the figure each inquiry component throughout the different stages in the program, through the dotted line. We note that the dotted line does not represent the pace of development but is there only for the purpose of the convenience of the follow up after a certain component.

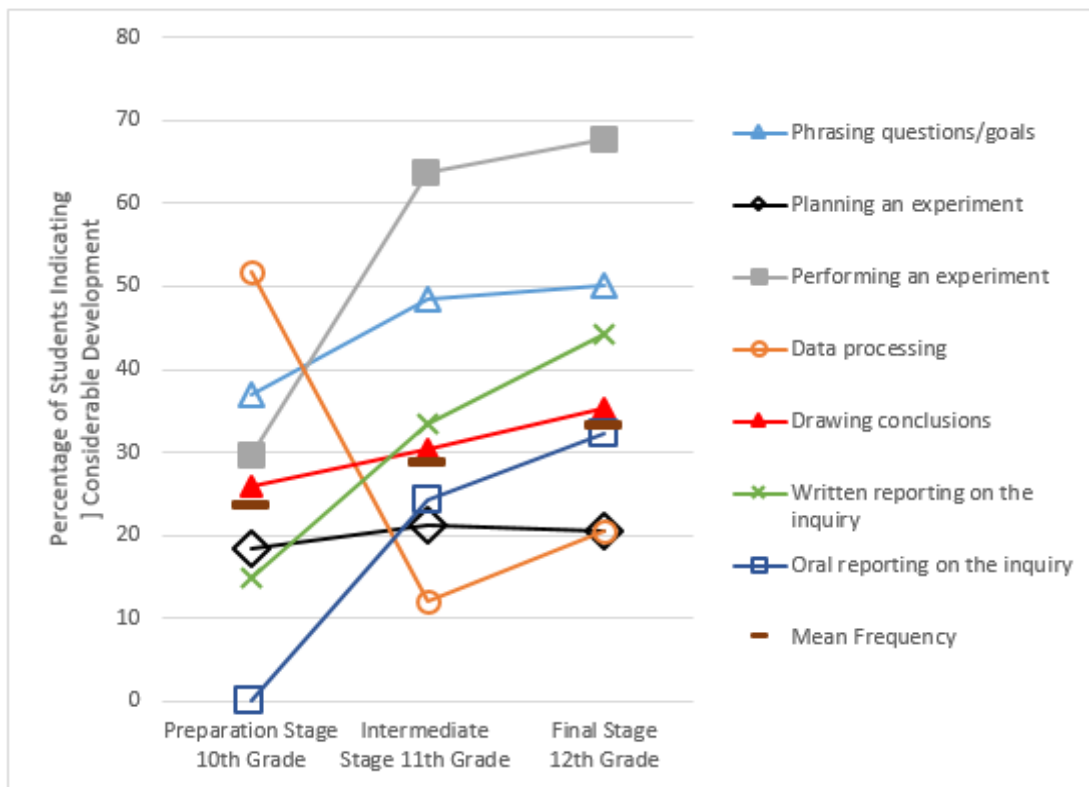


Figure 29: **Overall Picture** – Report of Students on the **Considerable Development** in the Different Inquiry Components in the Different Stages on the Inquiry Work: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)

We will focus on significant changes between the preparation stage and the final stage of the inquiry work. The following figure represents the students' reporting on the **considerable development** in the different inquiry components – comparison between the preparation stage of the inquiry project (in the second half of the 10th grade, N=27, before the submission of the mini-project report, from the Inquiry Skills Questionnaire) and the final stage (in the second half of the 12th grade, N=34, before the submission of the summative report, from the Summative Questionnaire (repeat)).

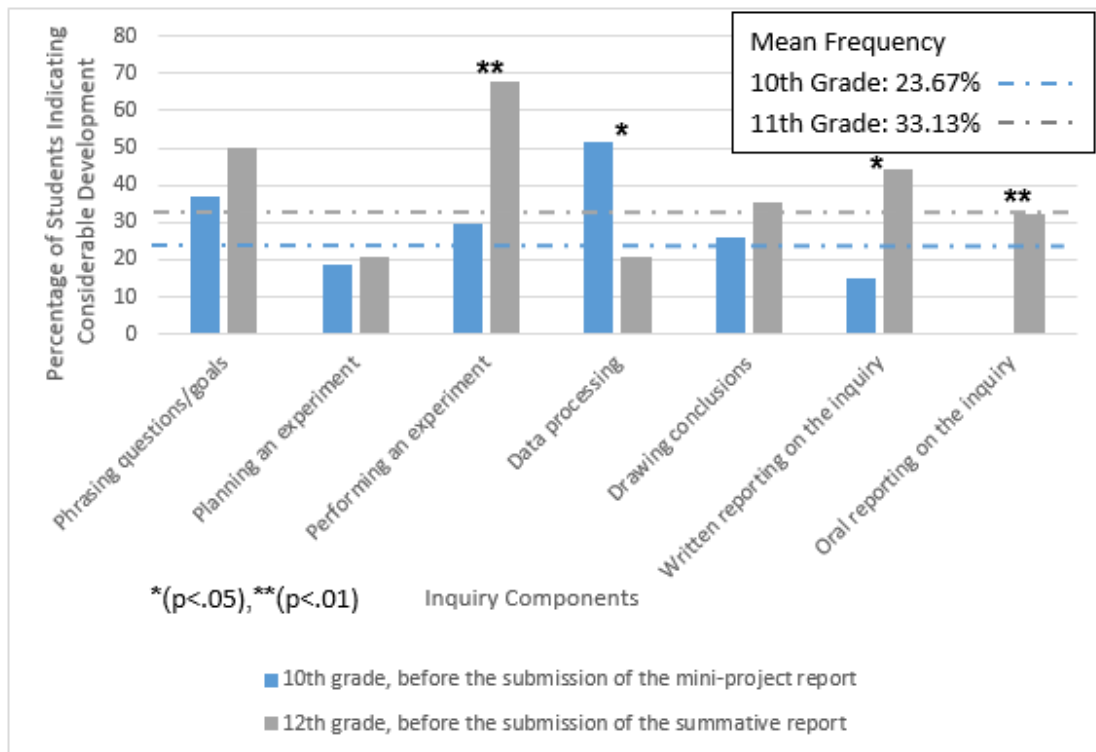


Figure 30: Report of Students on the **Considerable Development** in the Inquiry Components between the Preparation Stage (N=27) and the Final Stage (N=34) of the Inquiry Work

In the above figure, it was found that there is a significant difference, $\chi^2=28.9(14)$: $p<.001$, between the preparation stage and the final stage of the inquiry work in the percentage of the students who indicate considerable development in the inquiry components presented in the figure, as follows:

- It was found that there is a significant increase ($p < .05$) in the components of performing an experiment, written reporting on the inquiry, and oral reporting on the inquiry.
- It was found that there is a significant decline ($p < .05$) in the component of data processing.

To summarize, the three inquiry components in which many students (above the mean frequency) experienced significant development throughout all the research stages (at three different times in the program) are: phrasing questions/goals, performing an experiment, and drawing conclusions. In the component of performing an experiment, there is a significant increase from the preparation stage to the final stage of the inquiry work, while in the components of the phrasing of questions/goals and the drawing of conclusions there is no significant change between the stages, but there is a trend of increase towards the final stage of the inquiry work.

In addition, in the components of written reporting on the inquiry and oral reporting on the inquiry there is a significant increase between the preparation stage and the final stage of the inquiry work. In the component of written reporting on the inquiry many students (above the mean frequency) experienced significant development, towards the later stages of the inquiry work (towards the intermediate stage and the final stage of the project), while in the component of oral reporting on the inquiry towards the final stage of the inquiry the percentage that the students indicated is almost equal to the mean frequency. In other words, although the students indicated considerable development at a low percentage in the oral reporting of the inquiry, there is a significant increase between the preparation stage and the final stage of the inquiry work in this component.

In contrast, in the component of planning an experiment few students (under the mean frequency) reported considerable development throughout all the inquiry stages (at three different points of time in the program), and there is barely any change in the component of planning an experiment throughout all the inquiry stages. In addition, few students experienced significant development in the component of data processing towards the intermediate stage and even towards the final stage of the project, and there is a significant decline from the preparation stage to the intermediate stage of the inquiry work.

3.2.5.1.2 Students' Perception of the Degree of Their Development in the Performance of the Additional Inquiry Components Examined in the Last Two Stages

This subchapter presents main findings of the percentage of the students who indicate considerable development in the additional inquiry components relative to the mean frequency. To see the overall picture of the degree of development of the students in the performance of the additional inquiry components, we will look at the following figure.

The following figure represents the overall picture of the **students' reporting on their development in the performance of the additional inquiry components** in the last stages of the inquiry work: the intermediate stage of the inquiry project (in the second half of the 11th grade, N=33, before the submission of the intermediate report of the project) and the final stage of the inquiry project (in the second half of the 12th grade, N=34, before the submission of the summative report). We will note that the dotted line does not indicate the pace of development but is only for the purpose of the convenience of the follow up after a certain component.

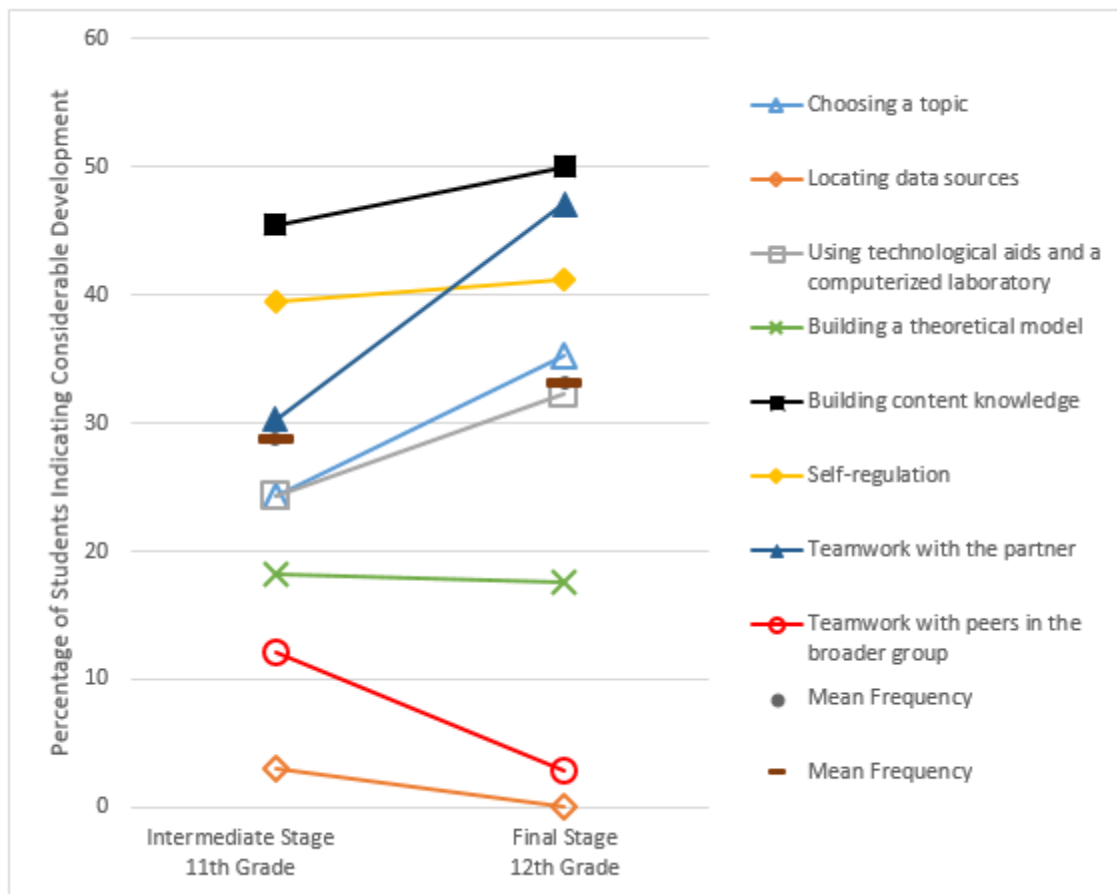


Figure 31: **Overall Picture** – Report of Students on the **Considerable Development** in the **Additional** Inquiry Components of the Inquiry Work: Intermediate Stage (N=33) and Final Stage (N=34)

To summarize, the additional inquiry components in which many students (above the mean frequency) experienced significant development both in the intermediate stage and in the final stage of the inquiry work are building content knowledge, self-regulation, and teamwork with the partner. Although there are no significant changes, there is a trend of increase in the component of teamwork with the partner and in the component of building content knowledge. In addition, many students (above the mean frequency) reported considerable development in the components of choosing a topic and the component of using technological aids and a computerized laboratory but only in the final stage of the inquiry work and there is a trend of increase from the intermediate stage to the final stage of the inquiry work.

In contrast, in the components of locating information sources, building a theoretical model, and teamwork with peers in the broader group few students (below the mean frequency) reported considerable development in the last two stages of the inquiry work. There is even a trend of decline in the percentage of the students who indicate considerable development primarily in the component of teamwork with the peers in the broader group.

3.2.5.2 Main Findings of the Qualitative Analysis – Main Aspects of Development that Arose from the Students’ Reports in Each Inquiry Component in the Different Stages of the Inquiry Work

According to the findings presented in the previous section, we will divide the inquiry components into groups: components in which many students (above the mean frequency) reported significant development throughout most of the inquiry stages, components in which many students (above the mean frequency) reported significant development but only in the final stage of the inquiry work, and inquiry components in which few students (below the mean frequency) reported significant development throughout most of the inquiry stages.

In each one of the groups, there is the description of the main aspects of development in the different inquiry components, as well as the stage in which they reported them. We will summarize the process that the students experienced throughout the inquiry work through tables. From the tables it is possible to look at the process that the students underwent throughout the inquiry work in the different aspects of the development in each stage and in the shared aspects of the different stages that the students experienced during the inquiry work.

1. Inquiry components in which many students (above the mean frequency) reported significant development throughout most of the inquiry stage.

- The inquiry components in which many students (above the mean frequency) experienced significant development throughout all the inquiry stages (stages 1, 2, and 3) are: **phrasing questions/goals, performing an experiment, and drawing conclusions.**

The following table describes the main developmental aspects arising from the students' reports in the inquiry components of phrasing questions/goals, performing an experiment, and drawing conclusions and the stage in which they were reported (index: stage 1 – preparation stage of the inquiry project, stage 2 – intermediate stage of the inquiry work, and stage 3 – final stage of the inquiry work).

Table 9: Main Aspects of Development Arising from the Students' Reports in the Inquiry Components: Phrasing Questions/Goals, Performing an Experiment, and Drawing Conclusions (Sigron, M)

Inquiry Components	Main Aspects of Development of the Students during the Inquiry Work	Stage	
Phrasing Questions/Goals	1. Improvement of the phrasing of the inquiry question, recognition of the structure of the inquiry question, which is composed of dependence of two physical sizes	1, 2	
	2. Awareness of the importance of choosing an interesting and open inquiry question that is sufficient to reach an in-depth inquiry	2	
	3. Knowing and coping dynamically with the inquiry question, which changes following developments during the inquiry work	2, 3	
	4. Focusing the inquiry question and avoidance of dispersion to a wide range of directions		
	5. Ability to ask investigable questions, which can develop to in-depth quantitative inquiry	3	
Performing an Experiment	1. Improvement of observations of the researched phenomenon	1	
	2. Performance of more complex experiments, which were not attempted in the past	2	
	3. Awareness of the importance of conducting initial experiments to understand the phenomenon, to build the knowledge	4. Duration of time of building the system and time of performing the experiment shortened	2, 3
		5. Awareness of the importance of the accuracy of measurement during the performance of the experiment in order to provide an accurate and focused response to the inquiry question	
		6. Building a better and more effective experiment system, which enables the isolation of variables, accuracy in the measurements, and minimization of the error factors as much as possible	
		7. Recognition that the performance of an experiment is a dynamic and changing performance during the inquiry work, so as to provide and accurate and focused response to the inquiry question	
8. Ability to solve problems during the experimental constellation and development of creativity and initiative to provide an answer to problems that arise in the experiment	3		
9. Awareness of the importance of the performance of experiments independently			
10. Ability to perform an experiment more independently than in the past			
11. Awareness of the importance of the reciprocal dependence between ownership of the inquiry and enjoyment of the research			

Drawing conclusions	1. Ability to find a relationship between two variables that were measured in the experiment and to describe it (without comparison to theory)	1
	2. Good ability of drawing conclusions from a comparison between the findings of the experiment and the theory, examination of the gaps between the theory and the experiment findings and giving explanations to these gaps	2, 3
	3. Understanding that when the results of the experiment are not commensurate with the theory they are not necessarily mistaken results but it is possible that they are real and correct results.	
	4. Good ability of drawing conclusions from comparison between the findings of the experiment and the findings of the computational modeling to obtain sharper conclusions	
	5. Recognizing and coping dynamically with drawing conclusions, which can change following the development in inquiry	
6. Focusing the conclusions, through examination, discussion of them, and filtering of some of the conclusions when doubt in their correctness is found	3	
7. Development of thinking, especially critical thinking in the process of drawing conclusions	1, 2, 3	

- In addition, the inquiry components in which many students (above the mean frequency) experienced significant development in the last two stages of the inquiry work (stages 2 and 3) are written reporting on the inquiry, building content knowledge, self-regulation, and teamwork with the partner. (We note that data was not collected in stage 1 about the components of building content knowledge, self-regulation, and teamwork with the partner in the preparation stage, and the reasons are detailed in the preface of the chapter of the findings of part A.)

The following table details main development aspects that arose from the students' reports in the inquiry components of written reporting on the inquiry, building content knowledge, self-regulation, and teamwork with the partner and the stage in which they reported them (index: index: stage 1 – preparation stage of the inquiry project, stage 2 – intermediate stage of the inquiry work, and stage 3 – final stage of the inquiry work).

Table 10: Main Aspects of Development Arising from the Students' Reports in the Inquiry Components: Written Reporting on the Inquiry, Building Content Knowledge, Self-Regulation, and Teamwork with the Partner (Sigron, M)

Inquiry Components	Main Aspects of Development of the Students during the Inquiry Work	Stage
Written Reporting on the Inquiry	<ol style="list-style-type: none"> 1. Familiarity with and use of the Word program 2. Familiarity with the correct structure of an experiment report and accumulation of experience in writing laboratory reports 	1
	<ol style="list-style-type: none"> 1. Awareness of the importance of documenting the inquiry in writing and its advantages 2. Improvement of the ability of documenting the inquiry process in the research journal, for more orderly, detailed, consistent, and ongoing documenting during the inquiry work 3. Improvement in writing presentations, for organized, concise writing (in which there are the main points) that is clear to the audience (and even shortening of the time required for writing and receiving enjoyment from the writing process) 	2, 3
	<ol style="list-style-type: none"> 1. Improvement in the level of writing of the summative work, both in the phrasing of the writing and in the organizing of all the work components, which includes all the parts of the structure of the experiment report and structure of the scientific work. 2. Improvement of the ability of control, differentiation between main and minor points, and making decisions in the examination of the work 	3
Building Content Knowledge	<ol style="list-style-type: none"> 1. In-depth and in-breadth understanding of the physical knowledge related to the researched phenomenon (for the most part contents beyond the high school curriculum), especially students who did not have previous knowledge. 2. Awareness of the importance of building content knowledge to carry out experiments so as to advance the inquiry and to make the practical inquiry deeper and more meaningful. 3. Awareness of the importance of taking responsibility for their learning and the need for investment to build the content knowledge. 4. Development of formula that link between physical sizes independently 5. Improvement of the ability of self-learning of the researched phenomenon and of different topics in general 6. Recognition of the need for openness in learning of new topics, increase of the curiosity and challenge in building content knowledge 	2, 3
Self-Regulation: In Planning & Organizing Inquiry Work	<ol style="list-style-type: none"> 1. Planning inquiry work in a more organized and effective manner than in the past 2. Awareness of the importance of planning and organizing the inquiry work and management of a work journal 3. Management of the inquiry work in a more independent manner than in the past 4. Increase of the work ethic and personal responsibility for the advance of the inquiry project, its quality, and its success 	2, 3
	<ol style="list-style-type: none"> 5. Critical thinking on the performances and inquiry process 	3

Self-Regulation: In Meeting Time Schedules	<ol style="list-style-type: none"> 6. Improvement in meeting time schedule through planning a good and orderly schedule, which combines the work of the inquiry project with other commitments 7. Awareness of the importance of planning time and meeting the schedule 	2, 3
Self-Regulation: In Coping in Situations of Lack of Certainty	<ol style="list-style-type: none"> 8. Recognition that situations of uncertainty during the inquiry work are a part of the inquiry process and it is possible from them to grow and deepen the investigation 9. Standing firm versus situations of uncertainty during the inquiry work more than in the past through the development of ability of perseverance, determination, and optimism 10. Development of creative thinking and awareness of the need for it so as to overcome situations of uncertainty during the inquiry process 	2, 3
	<ol style="list-style-type: none"> 11. Feeling of ownership and leadership of their inquiry project following increase of situations of uncertainty during the inquiry work 	3
Teamwork with the Project Partner	<ol style="list-style-type: none"> 1. Correct division of roles and work between partners that led to the improvement in the teamwork and effectiveness of the work 2. Sharing ideas and reciprocal fertilization with one another 3. Development of interpersonal skills, such as management of a respectful dialogue, giving a place to others' opinion, and for everyone to express in the work, flexibility and compromise on the part of each one of them, openness and trust in the partner 4. Development of social responsibility (to identify a situation of distress in the partner and to offer help), to provide backing and reciprocal support between the partners in the project mainly as necessary 5. Creation of deep friendships with the partner following close teamwork throughout the inquiry work 6. Awareness of the importance of good teamwork with the partner in the inquiry work because of its advantages, which leads to effective, quality, and enjoyable work 	2, 3

2. Inquiry components in which many students (above the mean frequency) reported significant development but only towards the final stage of the project: choosing a topic and using technological aids and a computerized laboratory.

The following table details main development aspects that arose from the students' reports in the inquiry components of choosing a topic and using technological aids and a computerized laboratory and the stage in which they reported them (index: index: stage 1 – preparation stage of the inquiry project, stage 2 – intermediate stage of the inquiry work, and stage 3 – final stage of the inquiry work).

Table 11: Main Aspects of Development Arising from the Students' Reports in the Inquiry Components: Choosing a Topic and Using Technological Aids and a Computerized Laboratory (Sigron, M)

Inquiry Components	Main Aspects of Development of the Students during the Inquiry Work	Stage
Choosing an Inquiry Topic	1. Awareness of the importance of choosing an inquiry topic that interests the learner and is selected by him 2. Recognizing that choosing a topic is not something obvious, it is necessary to use judgment	2
	3. Recognizing of the dynamic with the inquiry topic and investigation directions, which change during the performance of the inquiry 4. Focusing the inquiry topic and its in-depth investigation and avoidance of dispersion to different topics	2, 3
	5. Ability to make decisions independently, to choose an inquiry topic, directions of investigation, and a way of investigation	3
Using Technological Aids and a Computerized Laboratory	1. Knowing a space of new technological instruments and a computerized laboratory they did not know beforehand 2. Awareness of the importance and need for the use of technological tools and a computerized laboratory that enables greater depth and breadth on the researched phenomenon and even gives them a response to difficulties that arise during the performance of the inquiry	2, 3
	3. Recognizing additional advantages of the use of technological instruments and a computerized laboratory that significantly eases the method of investigation, raises the quality of the inquiry, and opens ideas to additional ways of investigation 4. Mastering the use of technological aids and a computerized laboratory	3

3. Inquiry components in which few students (below the mean frequency) reported significant development in most of the inquiry stages

- The inquiry stages in which few students (below the mean frequency) reported significant development throughout all the inquiry stages (1, 2, and 3): **Planning an experiment and oral reporting on the inquiry.**

The following table details main development aspects that arose from the students' reports in the inquiry components of planning an experiment and oral reporting on the inquiry, and the stage in which they reported them (index: index: stage 1 – preparation stage of the inquiry project, stage 2 – intermediate stage of the inquiry work, and stage 3 – final stage of the inquiry work).

Table 12: Main Aspects of Development Arising from the Students' Reports in the Inquiry Components: Planning an Experiment and Oral Reporting on the Inquiry (Sigron, M)

Inquiry Components	Main Aspects of Development of the Students during the Inquiry Work	Stage
Planning an Experiment	1. Awareness of the importance of the components of planning an experiment, which enables more orderly and organized work throughout the entire inquiry process	1
	2. Differentiation between major and minor points in the process of the planning of an experiment to choose the way of investigation	
	3. Awareness of the importance of the planning of an experiment independently (without receiving briefing ahead of time)	2
	4. The level of planning rose, to detailed planning that includes identifying and isolating variables 5. Recognizing that the planning of the experiment is a dynamic process in the inquiry work and changes according to the need of the investigation	2, 3
Oral Reporting on the Inquiry	6. The development of creativity and initiative to overcome the difficulties and to improve the planning of the experiment	3
	1. The reduction of the fear, embarrassment, and the pressure in the presentation before an audience compared to the past 2. Improvement of the performance of the oral presentation, both in the content of the presentation (presentation of the main points in the allotted time) and in the improvement of standing in front of an audience (that includes body language and improvement of the speech in a manner clear and understood to an audience)	2, 3
	3. Rise in the sense of efficacy and self-confidence to carry out a presentation in front of an audience	3

- In addition, the inquiry components in which few students (below the mean frequency) reported significant development in most of the inquiry stages (stages 2 and 3) are **locating information sources, data processing, building a theoretical model, and teamwork with peers in the broader groups**. (note that data was not collected in the first stage on the components of locating information sources, building a theoretical model, and teamwork with peers in the broader group, and the reasons are detailed in the preface of the chapter of the findings of part 3).

The following table describes main aspects of development arising from the students' reports in the inquiry components of locating information sources, data processing, building a theoretical model, and teamwork with peers in the broader groups and the stage in which they reported them (index: stage 1 – preparation stage of the inquiry project, stage 2 – intermediate stage of the inquiry work, and stage 3 – final stage of the inquiry work).

Table 13: Main Aspects of Development Arising from the Students' Reports in the Inquiry Components: Locating Information Sources, Data Processing, Building a Theoretical Model, and Teamwork with the Peers in the Broader Group (Sigron, M)

Inquiry Components	Main Aspects of Development of the Students during the Inquiry Work	Stage
Locating Information Sources	1. Improvement of the technique of searching for information sources on the Internet	2
Data Processing	1. Recognizing and accumulating experience in the use of computer programs (such as Excel)	1
	2. Ability to process data into graphical representation and improvement of graphical understanding	1, 2
	3. Awareness of the importance of data processing in a consistent and continuous manner after every experiment	2
	4. Ability to calculate the value of the error and evaluation of the range of uncertainty	2, 3
	5. Specialization in the use of computerized tools that enable professional data processing 6. Development of critical thinking following the engagement in data processing	3
Building a Theoretical Model	1. Familiarity with and experience in building a theoretical model using computational modeling (which they did not know beforehand) 2. Awareness of the importance of the engagement in the building of a theoretical model for the deeper understanding of the concepts and physical principles related to the investigated phenomenon and even to the discovery of additional phenomena	2, 3
	3. Expertise in writing a computer programming language following the building a theoretical model in a computerized manner	3
	1. Development of interpersonal skills of openness and trust between friends, the ability to ask for help from friends and to give help when necessary	2
Teamwork with Peers in the Broader Group	2. Awareness of the importance of teamwork with peers in the broader group, which is another source of receiving constructive criticism, support, help, and encouragement as necessary 3. Creation of a relationship with students from different places in Israel	3

The students described development in another inquiry component: identification with the world of scientific inquiry. This component does not have quantitative analysis since the students added it at their own initiative (in the possibility of “other”).

The following table describes main aspects of development arising from the students' reports in the inquiry component of identification with the world of scientific inquiry and the stage in which they reported them.

Table 14: Main Aspects of Development Arising from the Students' Reports in the Inquiry Component: Identifying with the World of Scientific Inquiry (Sigron, M)

Inquiry Components	Main Aspects of Development of the Students during the Inquiry Work	Stage
Identifying with the World of Scientific Inquiry	1. Experiencing the world of the scientist, in which people learn and research through discovery and inquiry, define a problem, search for and are committed to finding a solution, accompanied by curiosity and creativity.	2
	2. Knowing what the world of the researcher/scientist looks like and identification with the way in which the scientist experiences the inquiry process, which also includes difficult situations that he must overcome, simultaneously the discovery of the beauty in the doing of the inquiry itself and its products.	3

According to the findings, the observations of the student teams and the conversations with the program designers, recommendations were formed for each inquiry component separately (see in chapter 3.4 – Summary of the Findings for the First Research Question), which for the most part are commensurate with the students' reports on the factors that helped them develop in these inquiry components that were presented in the chapter (see 3.2.1, 3.2.2, 3.2.3 in each inquiry component separately in the different stages of the program).

In the chapter 3.1.5.2, which presents the qualitative analysis of part A (summary of main findings of the challenges of the students) and in this chapter which presents the qualitative analysis of part B (summary of main findings of the developmental aspects of the students), it is possible to see that in certain inquiry components some of the difficulties reported by the students are the same aspects that the students noted that they developed in. Is it possible that the coping with the challenges constituted the possibility for growth and development of the students in certain inquiry components? This will be addressed in the third part, C, of the first question. The following sub-chapter will present the findings of this part, part B of the first research question, the students' perception of their development in the different inquiry components, versus the findings of the previous sub-chapter, part A of the first research question, the students' perception of their experience and challenge in the performance of the inquiry components. The aim is to find the correlation between the development, experience, and challenges in the performance of the inquiry components in the different stages of the program.

3.3 Findings for Part C of the First Research Question: The Relationship between Development, Experience, and Challenges Experienced by the Students in the Performance of the Different Inquiry Components

This sub-chapter presents the processing of the findings²⁴ in response to part C of the first research question.

C) Students' development, following students' experience and challenge in each stage of the program:

- How did the extent of the students' development in the various inquiry components relate to the extent of experience and challenge in these components?
- How do the experiences, challenges, and development, as perceived by the students, correspond to the observed experiences, challenges and development?

To see clearly the relationship between the development, experience, and challenge that the students experienced in the performance of the different inquiry components in different stages in the program, this chapter presents the findings of part A, the students' perception of the experience and challenge in the performance of the different inquiry components, versus the findings of part B, the students' perception of their development in the different inquiry components.

3.3.1 Stage 1: Preparation Stage of the Inquiry Project (10th Grade) – Relationship between Development, Experience, and Challenge in the Performance of the Different Inquiry Components (in light of the Observation)

This section presents the processing of the findings of the students' reports on the development, experience, and challenge in the performance of the different inquiry components in the stage of the preparation of the inquiry project (self-reporting questionnaire before the submission of the mini-project report, tenth grade), from the Inquiry Skills Questionnaire (see appendix number 1.2), N=27. There is no teacher-mentor attached to every team of students; rather two teacher-mentors from the program accompany and support all the teams. In this questionnaire, the students were asked to

²⁴ From quantitative & qualitative instruments: Preliminary questionnaire (N=33), Inquiry skills questionnaire (N=27), Summative questionnaire (first N=33, second N=34), Observation of the students' activities

choose at least two inquiry components in which, in their opinion, they had considerable experience during the inquiry work, at least two inquiry components in which in their opinion they experienced considerable difficulty during the inquiry work, and at least two inquiry components in which in their opinion they developed greatly during the inquiry work.

3.3.1.1 Stage 1 – Relationship between Development and Experience in the Performance of the Different Inquiry Components

The following figure represents the students’ self-reporting on the considerable development / experience in the performance of the inquiry components in the second half of the tenth grade, N=27, before the submission of the mini-project report (from the Inquiry Skills Questionnaire).



Figure 32: Self-Reporting of Students on the **Considerable Development/Experience** in the Performance of the Inquiry Components, 10th Grade (N=27)

To represent clearly the relationship between the development and the experience in the performance of the different inquiry components, the characterization of the inquiry components that deviate above/below the mean frequency was performed. As will be

shown in the following figure 33. The mean frequency is the percentage of mean indication of all the inquiry components. The mean frequency in this stage regarding development is 23.67%, while the mean frequency regarding experience is 62.96%.

In the following figure, the axes represent the degree of positive or negative deviation from the mean frequency of students who indicated considerable development (Y axis) and considerable experience (X axis) in the different inquiry components. Namely, the origin represents the mean frequency of students who indicated considerable development/experience. The vertical position of the inquiry components represents the degree of deviation in the aspect of development – as the placement of the inquiry component is higher in the figure, the frequency of the students who indicated considerable development in this component is greater.

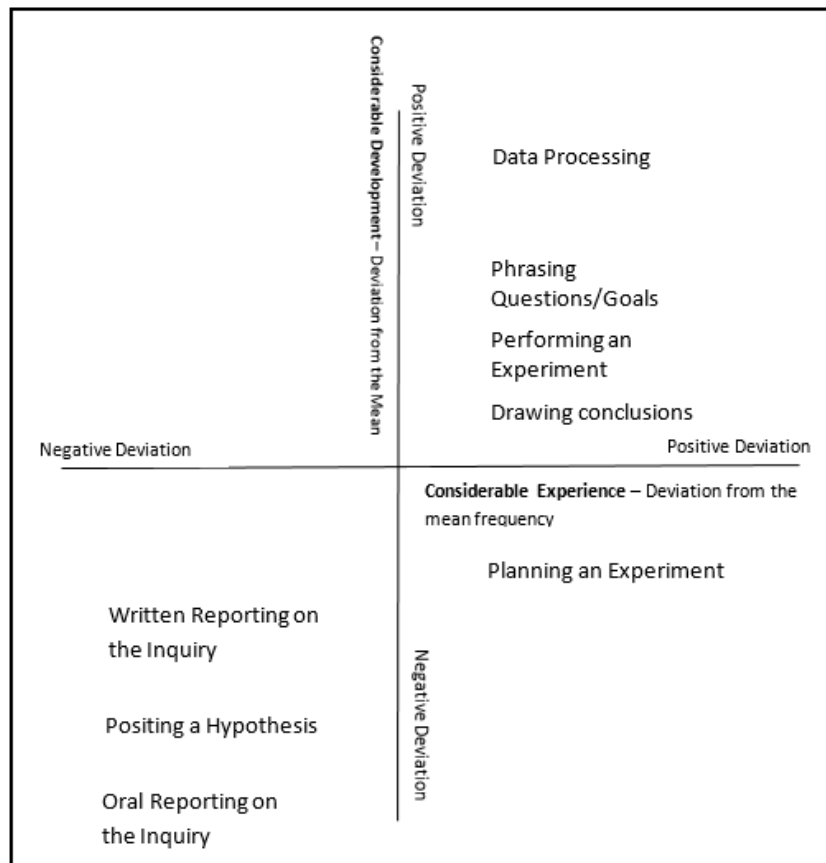


Figure 33: Relationship between **Considerable Development** and **Considerable Experience** in the Performance of the Different Inquiry Components (Representation of the Deviation from the Mean Frequency – Development 23.67%, Experience 62.96%)

10th Grade (N=27) (Sigron, M)

3.3.1.2 Stage 1 – Relationship between Development and Challenge in the Performance of the Different Inquiry Components

The following figure represents the students' self-reporting on the considerable development / difficulty in the performance of the inquiry components in the second half of the tenth grade, N=27, before the submission of the mini-project report (from the Inquiry Skills Questionnaire).

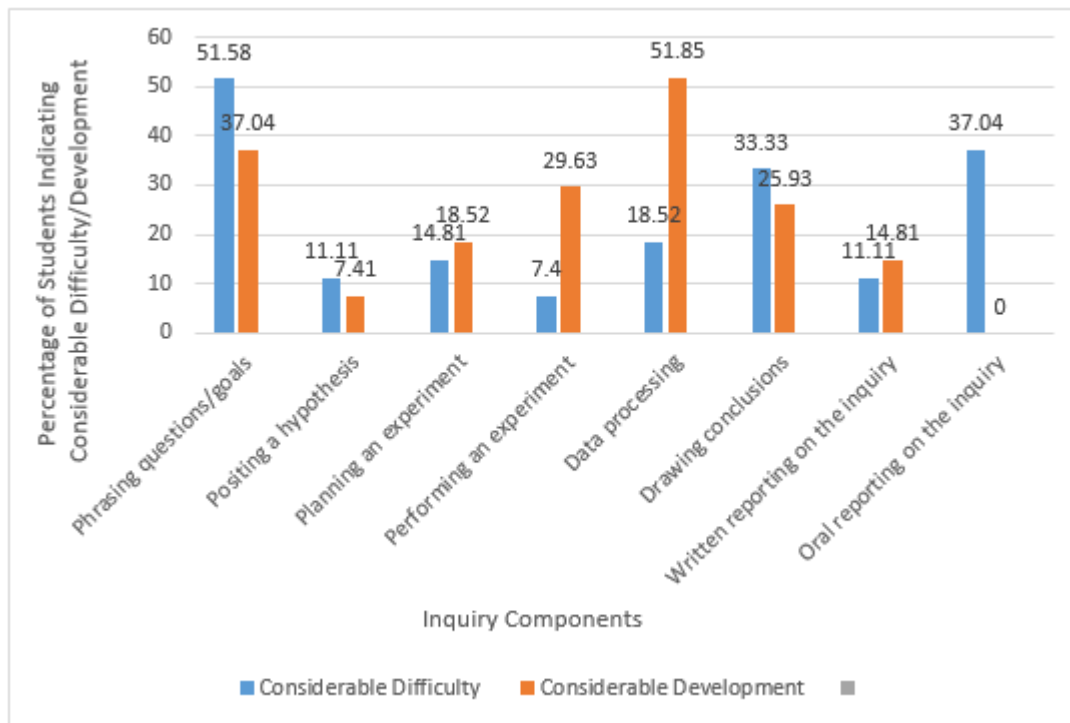


Figure 34: Self-Reporting of Students on **Considerable Development/Difficulty** in the Inquiry Components, 10th Grade (N=27)

To represent clearly the relationship between the development and the challenge in the performance of the different inquiry components, mapping was done of the inquiry components that deviate above/below the mean frequency. As will be shown in the following figure 35. The mean frequency is the mean percentage indicating all the inquiry components. The mean frequency in this stage regarding development is 23.67%, and the mean frequency regarding difficulty is 23.11%.

In the following figure, the axes represent the degree of positive or negative deviation from the mean frequency of students who indicated considerable development (axis Y) and considerable difficulty (axis X) in the different inquiry components. Namely, the origin represents the mean frequency of the students who indicated considerable development/difficulty. The vertical position of the inquiry components represents the degree of deviation in the aspect of development – as the place of the inquiry component is higher in the figure, the frequency of the students who indicated considerable development in this component is greater.

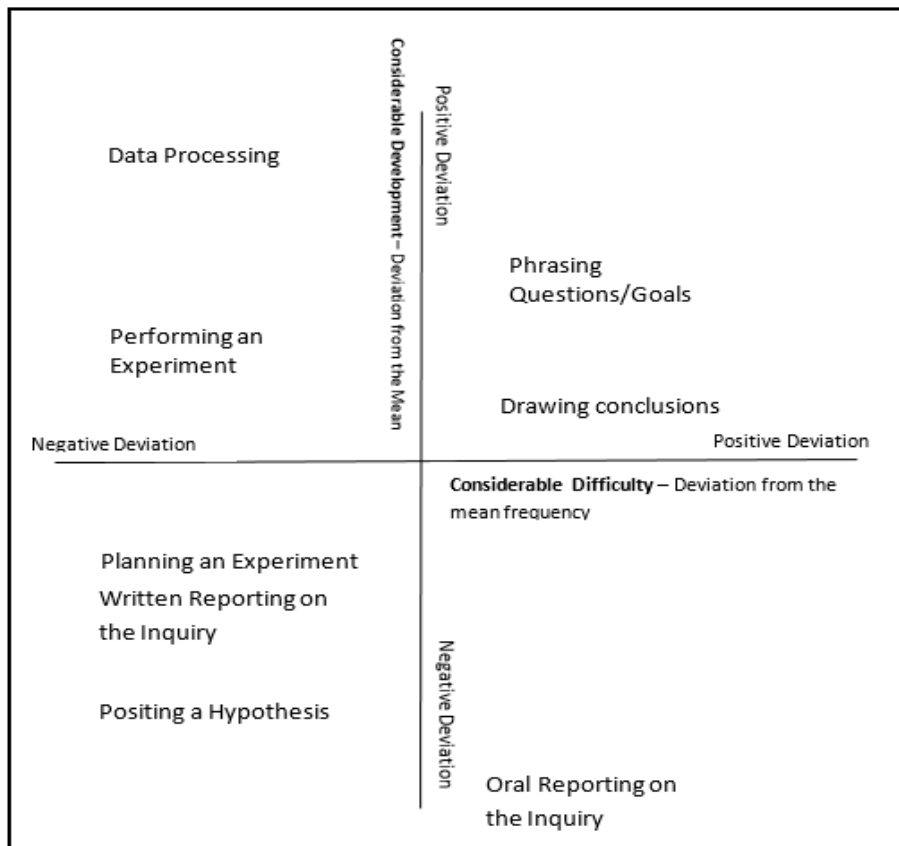


Figure 35: Relationship between **Considerable Development** and **Considerable Difficulty** in the Performance of the Different Inquiry Components (Representation of the Deviation from the Mean Frequency –Development 23.67%, Difficulty 23.11%)
10th Grade (N=27) (Sigron, M)

3.3.1.3 Main Findings – The Relationship between Development and Experience and between Development and Challenge in the Performance of the Different Inquiry Components in light of the Observation - Stage 1 (Preparation Stage of the Inquiry Project)

Following the quantitative analysis and in light of the observation, this subchapter will present an interim Summary and discussion of the relationship between the development and experience and challenge in the different inquiry components that the students experienced in stage 1, the stage of the preparation of the inquiry project (tenth grade).

The findings from the Inquiry Skills Questionnaire in the second half of the first year of the program in the tenth grade (May 2017) were processed. This questionnaire was held during the inquiry work on the mini-project, before the submission of the written report and before the presentation in front of the audience. Then the students experienced beforehand preparation activities, which have the taste of inquiry, and the students worked on inquiry practices such as asking questions, planning an experiment and performing it, drawing conclusions, teamwork, and so on. However, these activities were for the short-term, up to two sessions for every activity, so that it was not possible to reach the fulfillment in the acquisition of every practice. The inquiry activity on the mini-project was for a longer period, four meetings, and in it students needed to research in greater depth about one of the physical phenomena they saw in the Clore Garden of Science Museum at the Weizmann Institute and use all the inquiry practices they acquired in the previous activities.

The following figure presents two figures 33,35 side by side, so that it is possible to clearly see the relationship between development and experience and challenge in the performance of the different inquiry components in stage 1 (the stage of the preparation of the inquiry project) (from the Inquiry Skills Questionnaire, before the submission of the report of the mini-project, in the first year of the program, May 2017).

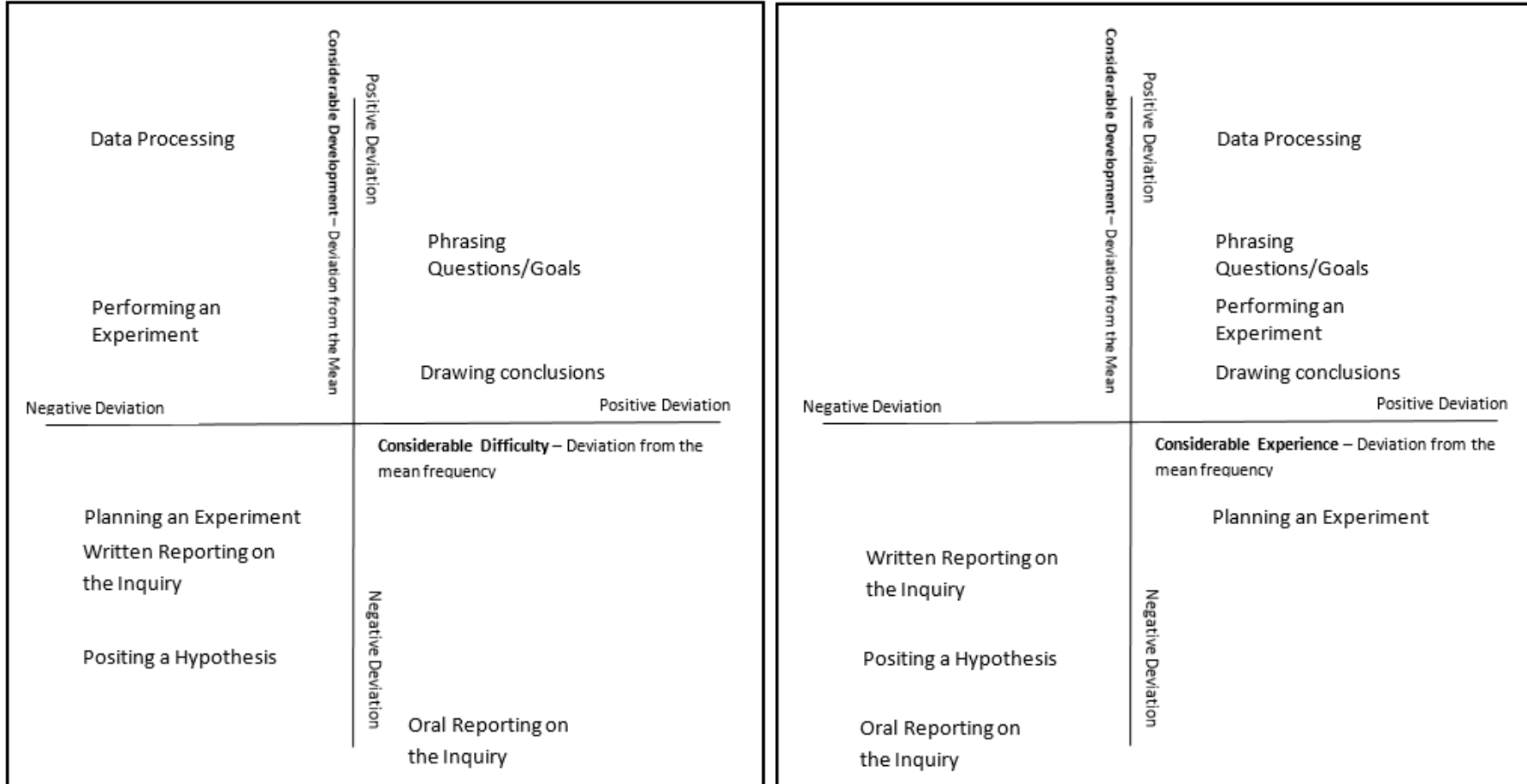


Figure 36: **Relationship between Considerable Development and Considerable Experience/Difficulty in the Performance of the Different Inquiry Components** (Representation of the Deviation from the Mean Frequency – Development 23.67%, Experience 62.96%, Difficulty 23.11%), Stage 1 – 10th Grade (N=27) (Sigron, M)

Main Findings of the Above Figures

In the inquiry components of phrasing questions/goals, performing an experiment, data processing, and drawing conclusions, many students (above the mean frequency) report that they experienced and developed greatly. Among these components, it is possible to see that the development is commensurate with the experience and challenge in two inquiry components: phrasing questions/goals and drawing conclusions. In other words, the experience the students report of considerable experience in these components and considerable coping with the challenges innate in the performance of these components is commensurate with the report of considerable development among many students (above the mean frequency).

In two other components, performing an experiment and data processing, many students (above the mean frequency) report considerable development, which is commensurate with the report of considerable experience. However, this is accompanied by the report of lack of challenge.

In the components of written reporting on the inquiry and positing a hypothesis, the students report they did not experience greatly and were also not especially challenged. Few students (below the mean frequency) report that they developed greatly in these components.

In the component of oral reporting on the inquiry the students report the great challenge and little experience, and only a few students (below the mean frequency) report considerable development.

In the component of planning an experiment, despite the report of great experience, few students (below the mean frequency) report considerable development in this component.

Description and Discussion of the Findings in light of the Observation

The inquiry components in which many students (above the mean frequency) report that they experienced and developed considerably are phrasing questions/goals, performing an experiment, data processing, and drawing conclusions. This is commensurate with the structure of the intervention in actuality and to the observations – the preparation activity

for the inquiry required the students to choose the phenomenon, to identify the problem that they want to address, to phrase an inquiry question according to the problem, to perform an experiment that will provide a response to their question, and to phrase conclusions from the processing of the data. The students experienced development in these components, which are different from their experience in the laboratory in the classroom, where for the most part the students receive a briefing that dictates the questions and the ways of performance, and last a discussion is held in the plenum and the summary of the conclusions of the experiment by the teacher. Of these components, phrasing questions/goals and drawing conclusions, many students (above the mean frequency) report considerable difficulty in the performance of these components, which is commensurate with the reporting on considerable development. The common denominator of these components is that to perform require strategies from higher order thinking, such as synthesis, analysis, and differentiation between the major and less important points. It is reasonable to assume that the experience and challenge contributed to the development of the students in these components.

In two other components, performing an experiment and processing data, many students (above the mean frequency) had considerable experience but few students (below the mean frequency) had considerable difficulty in the performance of these components, and nevertheless many students have experienced considerable development. It is reasonable to assume that the very experience was enough to enable development in these components. This is commensurate with the structure of the intervention in actuality and with the observations – in the preparation stage the students performed basic experiments for short activities in which there is a taste of inquiry and in this stage the students engaged in basic data processing, and for the most part it is technical performance (the main point is writing the results of the experiment in a table in an electronic spreadsheet, for instance in Excel, transfer to graphical representation; some performed linearization and added a trend line), which can explain the fact that they did not experience great difficulty. However, the very familiarity with the Excel software (in which some of them had a little experience) gave them a means for the collection and processing of data in an optimal manner, and therefore the students reported considerable development in the component of data processing.

The inquiry components in which few students (below the mean frequency) report that they experienced and developed considerably are: positing a hypothesis, written reporting on the inquiry, and oral reporting on the inquiry (a component in which there was no development). Indeed, in this stage of the program the students barely had experienced these components as they report, so meaningful development was not possible at the point of time of the questionnaire (this questionnaire was held during the inquiry work on the mini-project, before the submission of the report in writing and before the presentation before the audience). In light of the observations, in the first activities of the preparation stage only a small number of the students orally presented their products. Thus, only towards the end of the year, all the students were required to report on their work in writing and orally. In addition, the students did not have an opportunity to learn and to improve their performances in these components and accordingly they did not reach a high level of performance.

In the component of oral reporting on the inquiry, many students (above the mean frequency) report considerable difficulty, while in the components of positing a hypothesis and written reporting on the inquiry few students report this. In the preparation stage, the component of written reporting on the inquiry addresses the writing of partial and basic experiment reports for short activities and writing short feedback on the activity according to guiding questions (at the end of every activity the students answers two questions of the program teacher-mentors), thus explaining the fact that they did not experience considerable difficulty in this component. In the component of positing a hypothesis, the students first posited a hypothesis, but then they did not dedicate time to the theoretical establishment of the hypothesis and they were not asked to explain their hypothesis or offer a possible explanation of their hypothesis from existing scientific knowledge or from their previous knowledge. Hence, the students were not especially challenged, and only a few students reported considerable development in these components. Regarding the component of the oral reporting on the inquiry, it is reasonable to assume that the great challenge, along with the little experience, did not enable considerable development among many students in this component. In addition, less support that was required from the outside was given for this component.

Regarding the component of planning an experiment, only a few students (below the mean frequency) report considerable development despite the considerable experience and they were not even especially challenged. It is possible to explain this in the emphases of instruction that the students received in this component. In light of the observation, the component of planning an experiment was required but was not handled explicitly. A planning strategy was not suggested, and there was no feedback on the planning, and accordingly the students did not receive the required direction to specialize in this component. It is necessary to hypothesize that the little emphasis derived from the short time given to the activity in the preparation stage. The time did not enable a round of improvements of the experiment that would examine the initial planning and update it. Accordingly, only a few students experienced considerable development in this component.

3.3.2 Stage 2: Intermediate Stage of the Inquiry Project (11th Grade) – Relationship between Development, Experience, and Challenge in the Performance of the Different Inquiry Components (in light of the Observation)

This section presents the processing of the findings of the students' reports on development, experience, and challenges in the performance of the different inquiry components in the intermediate stage of the inquiry project (self-reporting questionnaire before the submission of the intermediate report, eleventh grade), from the Summative Questionnaire (see Appendix Number 1.4), N=33. The questionnaire was held before the submission of the intermediate report of the project, in the second half of the eleventh grade (April 30, 2018), after the oral presentation in front of the peers, when there is a teacher-mentor for each research team. In this questionnaire, the students were asked to choose at least two inquiry components in which in their opinion they experienced considerably during the inquiry work, at least two inquiry components in which in their opinion they experienced considerable difficulty during the inquiry work, and at least two inquiry components in which in their opinion they developed considerably during the inquiry work.

3.3.2.1 Stage 2 – Relationship between Development and Experience in the Performance of the Different Inquiry Components

The following figure represents the students' self-reporting on the considerable development/experience in the performance of the inquiry components in the second half of the eleventh grade, N=33, before the submission of the intermediate report of the inquiry project (from the Summative Questionnaire).

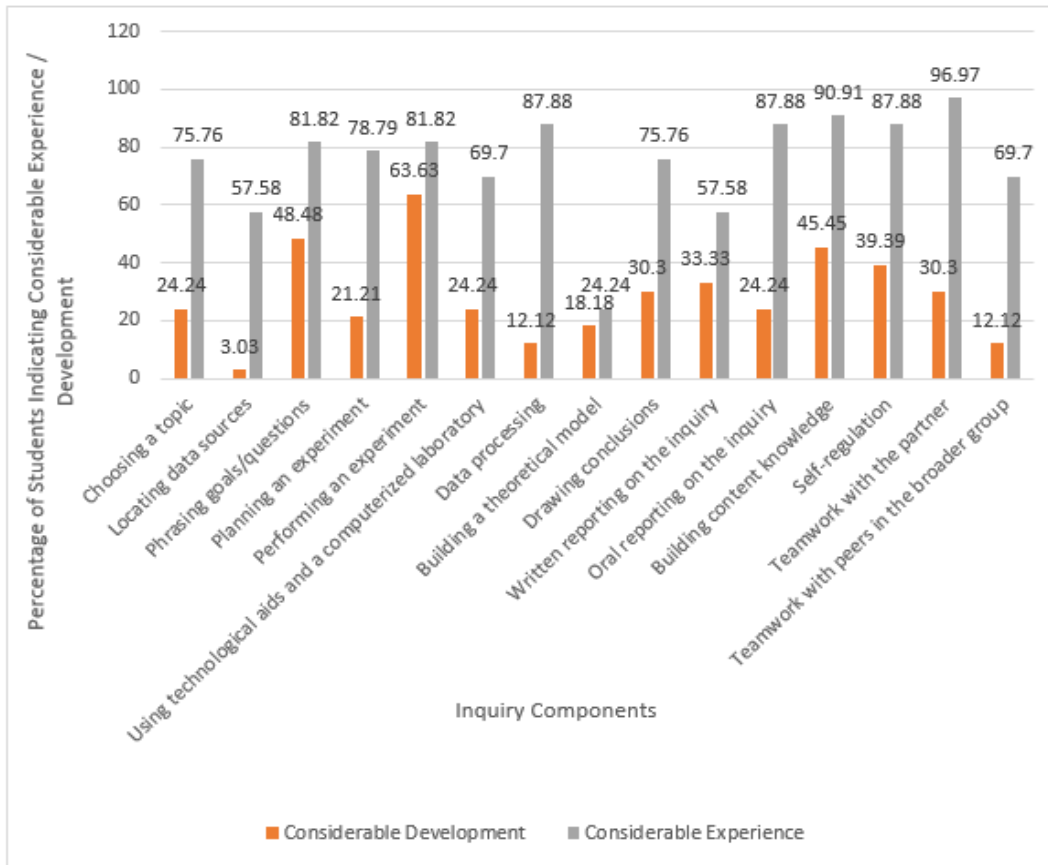


Figure 37: Self-Reporting of Students of **Considerable Development/Experience** in the Performance of the Inquiry Components, 11th Grade (N=33)

To clearly represent the relationship between the development and the experience in the performance of the different inquiry components, mapping was performed of the inquiry components that deviate above/below the mean frequency. As will be shown in the following figure 38. Mean frequency is the mean percentage of indication of all the inquiry components. The mean frequency in this stage regarding the development is 28.68%, the mean frequency regarding experience is 74.95%.

In the following figure, the axes represent the degree of the positive or negative deviation from the mean frequency of the students who indicated considerable development (Y axis) and considerable experience (X axis) in the different inquiry components. Namely, the origin represents the mean frequency of students who indicated considerable development/experience. The vertical positioning of the inquiry components represents the degree of deviation in the aspect of development – as the position of the inquiry component is higher in the figure, the frequency of the students who indicated considerable development in this component is greater.

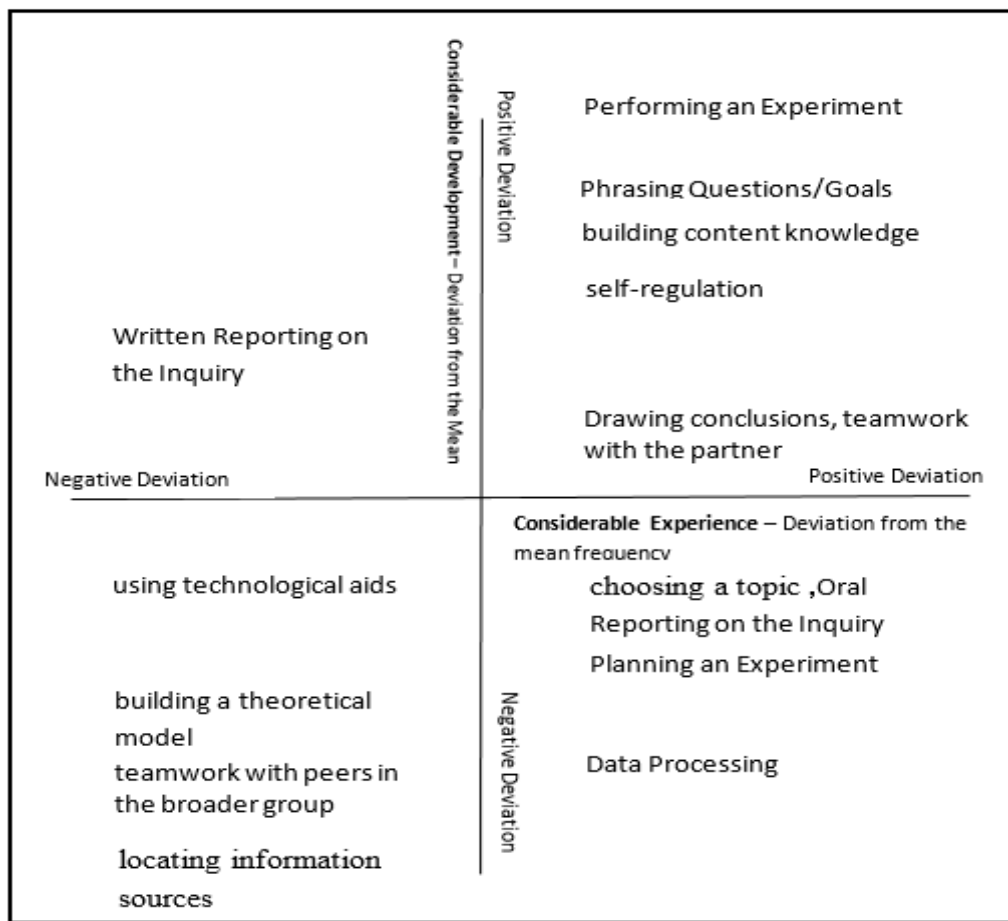


Figure 38: Relationship between **Considerable Development** and **Considerable Experience** in the Performance of the Different Inquiry Components (Representation of the Deviation from the Mean Frequency – Development 28.68%, Experience 74.95%),
11th Grade (N=33) (Sigron, M)

3.3.2.2 Stage 2 – Relationship between Development and Challenge in the Performance of the Different Inquiry Components

The following figure represents the students' self-reporting on the considerable development/difficulty in the performance of the inquiry components in the second half of the 11th grade, N=33, before the submission of the intermediate report of the inquiry project (from the summative questionnaire).

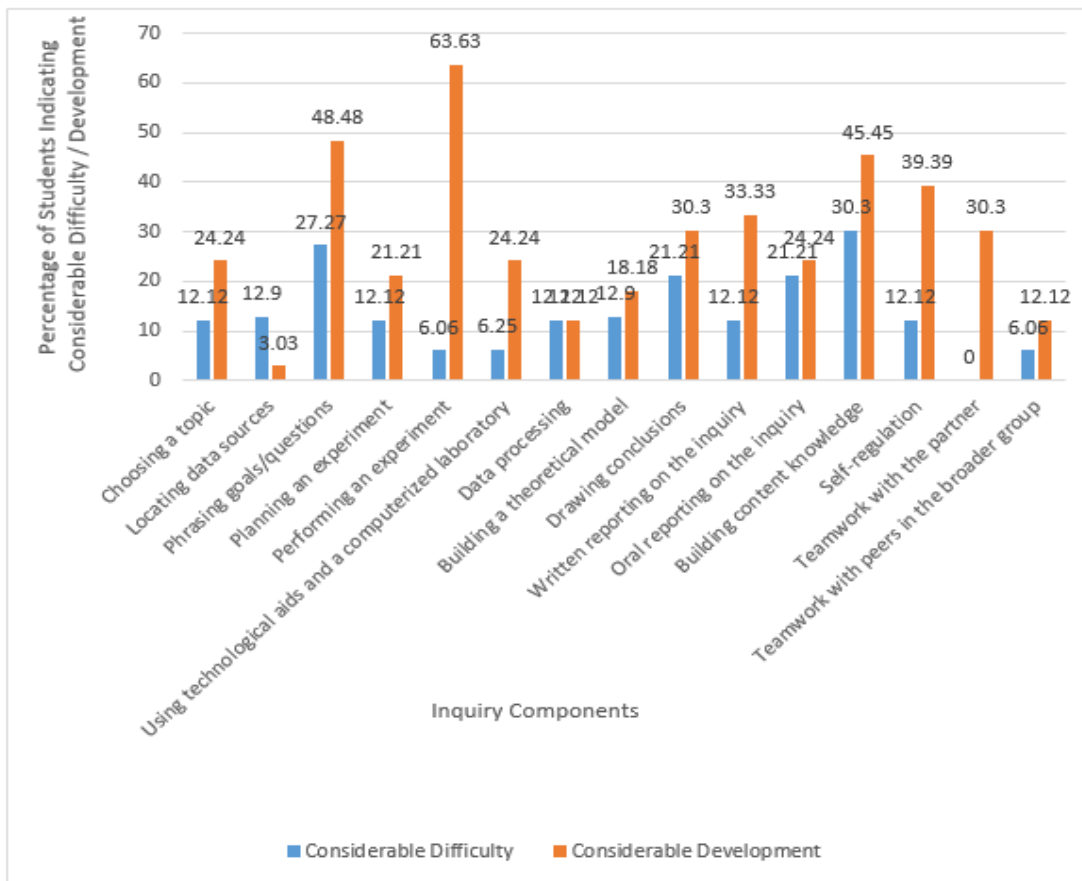


Figure 39: Self-Reporting of Students on the **Considerable Development/Difficulty** in the Performance of the Inquiry Components, 11th Grade (N=33)

To represent clearly the relationship between the development and the challenge in the performance of the different inquiry components, mapping was done of the inquiry components that deviate above/below the mean frequency. As will be shown in the following figure 40. The mean frequency is the mean percentage indicating all the inquiry

components. The mean frequency in this stage regarding development is 28.68%, and the mean frequency regarding difficulty is 13.65%.

In the following figure, the axes represent the degree of positive or negative deviation from the mean frequency of the students who indicated considerable development (Y axis) and considerable difficulty (X axis) in the different inquiry components. Namely, the origin represents the mean frequency of students who indicated considerable development/difficulty. The vertical positioning of the inquiry components represents the degree of deviation in the development aspect – as the positioning of the inquiry components is higher in the figure, the frequency of the students who indicate considerable development in this component is greater.

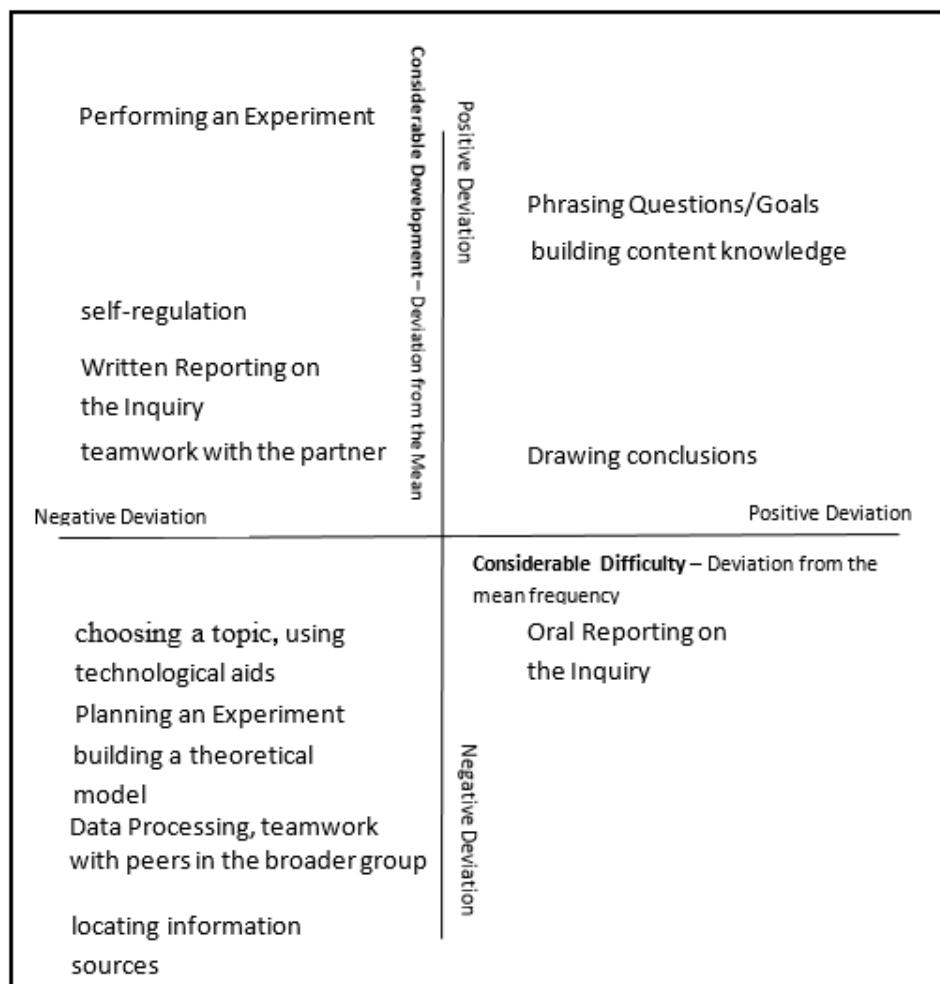


Figure 40: Relationship between **Considerable Development** and **Considerable Difficulty** in the Performance of the Different Inquiry Components (Representation of the Deviation from the Mean Frequency – Development 28.68%, Difficulty 13.65%),
11th Grade (N=33) (Sigron, M)

3.3.2.3 Main Findings – The Relationship between Development and Experience and between Development and Challenge in the Performance of the Different Inquiry Components in light of the Observation - Stage 2 (Intermediate Stage of the Inquiry Project)

Following the quantitative analysis and in light of the observation, this subsection will present an interim Summary and discussion of the relationship between development and experience and challenge in the different inquiry components that the students experienced in stage 2, the intermediate stage of the inquiry project (eleventh grade).

The findings from the Summative Questionnaire, which was held in the second half of the second year of the program, in the eleventh grade (April 30, 2018) were processed. This questionnaire was held after the students' presentation of the intermediate report of the project. In this year, the students performed initial experiments in order to understand the researched phenomenon, which constitute the basis of the final project, and engaged in the search for and choice of directions of investigation for the advancement and increased depth of the project. Throughout the year, there was close instruction for the entire research staff of students.

The following figure presents two figures 38,40 side by side, so that it is possible to clearly see the relationship between development and experience and challenge in the performance of the different inquiry components in stage 2 (the intermediate stage of the inquiry project) (from the Summative Questionnaire, held before the submission of the intermediate report of the project, in the second year of the program (April 30, 2018)).

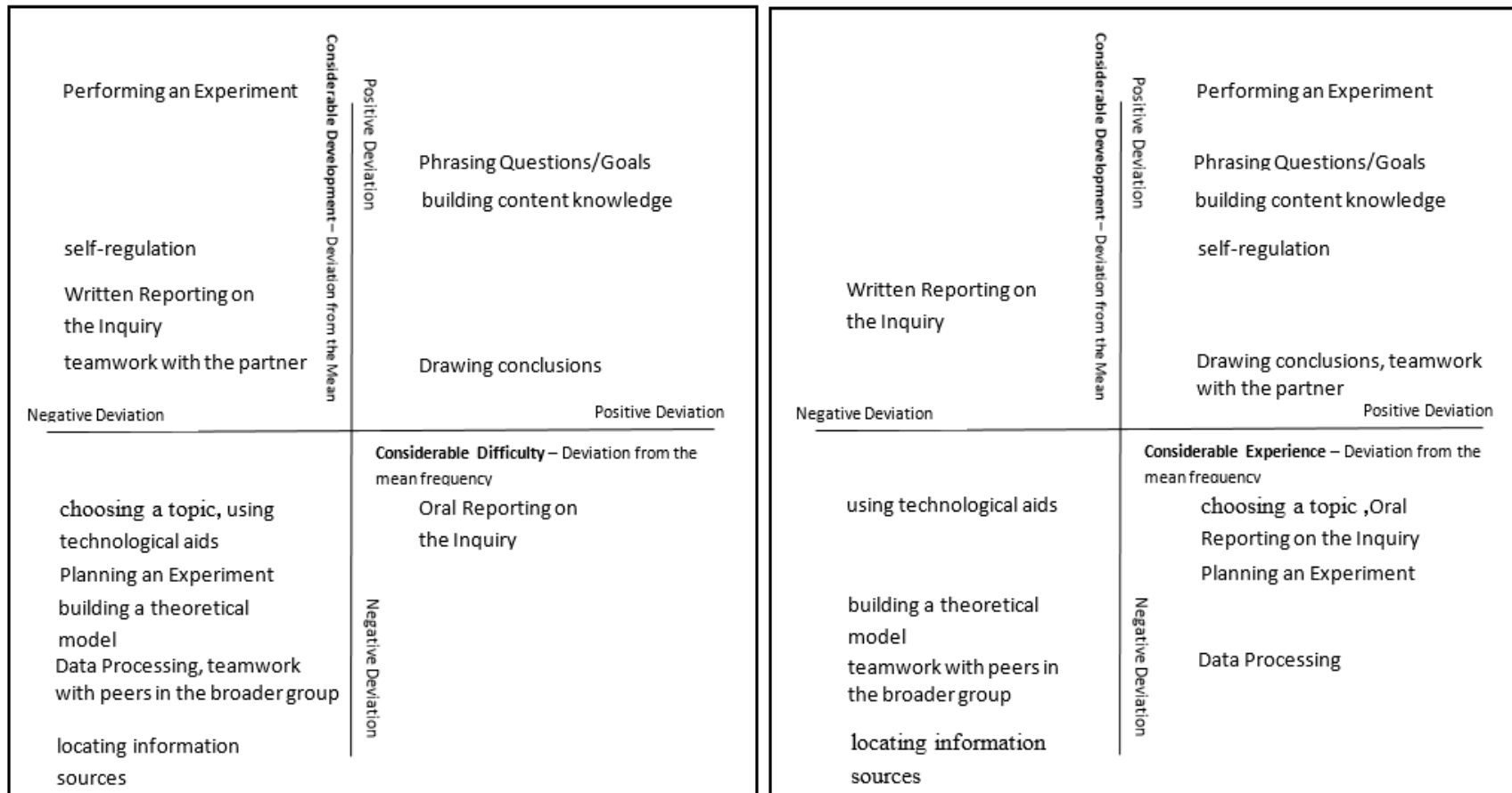


Figure 41: **Relationship between Considerable Development and Considerable Experience/Difficulty** in the Performance of the Different Inquiry Components (Representation of the Deviation from the Mean Frequency – Development 28.68%, Experience 74.95%, Difficulty 13.65%), Stage 2 – 11th Grade (N=33) (Sigron, M)

Main Findings of the Above Figures

In the inquiry components of phrasing questions/goals, performing an experiment, drawing conclusions, building content knowledge, self-regulation, and teamwork with the partner, many students (above the mean frequency) report that they experienced and developed considerably. Of these components, it is possible to see that the development is commensurate with the experience and challenge in the three inquiry components: phrasing questions, drawing conclusions, and building content knowledge. In other words, the experience that the students report, of considerable experience in these components and considerable coping with challenges entailed by the performance of these components, is commensurate with the reporting of considerable development among many students (above the mean frequency).

In other inquiry components, performing an experiment, self-regulation, and teamwork with the partner, many students (above the mean frequency) report considerable development, which is commensurate with the reporting on considerable experience but is accompanied by reporting on lack of challenge.

In the inquiry components of locating information sources, using technological aids and computerized laboratory, building a theoretical model, and teamwork with the rest of the peers, the students report that they did not experience greatly, were also not especially challenged, and accordingly only a few students (below the mean frequency) report that they developed considerably in these components.

In the inquiry components of choosing a topic, oral reporting on the inquiry, planning an experiment, and data processing, despite the reporting of considerable experience, few students (below the mean frequency) report considerable development. It is necessary to notice that in the component of the oral reporting on the inquiry many students (above the mean frequency) report considerable difficulty with performance. In the component of written reporting on the inquiry, many students (above the mean frequency) report considerable development although they did not experience much and were not especially challenged in the performance of this component.

Description and Discussion of the Findings in light of the Observation

The inquiry components in which many students (above the mean frequency) report that they experienced and developed greatly are phrasing questions/goals, performing an experiment, drawing conclusions, building content knowledge, self-regulation, and teamwork with the partner. This is commensurate with the structure of intervention in actuality and with the observations – in this stage the students conducted initial experiments to understand the researched phenomenon and physical concepts related to it. In parallel, the students needed to structure the content knowledge relevant to the inquiry topic independently and with the teacher-mentors' support (every pair of students is accompanied by a teacher-mentor). In addition, the annual inquiry project required teamwork and self-regulation to work effectively and to advance in the inquiry work. It is reasonable to assume that the considerable experience in these inquiry components over time contributes to the students' development in these components. Of these components, the phrasing of questions/goals, the drawing of conclusions (like in the previous questionnaire, in the preparation stage), and the building of content knowledge, many students (above the mean frequency) report considerable difficulty in the performance of these components, which is commensurate with the reporting on the considerable development. The common denominator of these components is that to perform them the implementation of higher order thinking is necessary, as well as the in-depth understanding of the principles and concepts relevant to inquiry, synthesis, and analysis. It is reasonable to assume that the experience and challenge contributed to the students' development in these components.

In other components, performing an experiment, self-regulation, teamwork with the partner, many students (above the mean frequency) had considerable experience, but few students (below the mean frequency) had considerable difficulty with the performance of these components, and nevertheless many students reported considerable development. Regarding the component of performing an experiment, the experiments that were held were not yet complex relative to the continuation of the investigation but were initial experiments that constitute a basis for the final project and for deciding upon the inquiry directions, and it is reasonable to assume that the very experience was enough to allow development in this component. Regarding the two components of teamwork and self-

regulation, it is reasonable to assume that the close instruction (every research team had a close teacher-mentor) contributed to the students' development and eased the difficulty of the performance of these components. The close teacher-mentor encouraged teamwork between the partners throughout the inquiry work and gave direction to the division of work between the partners and to the setting of the time schedule. In addition, support was given as necessary, especially when the students reached a situation of uncertainty or powerlessness so as to advance in the inquiry, with the attempt of most of the teacher-mentors not to harm the students' feeling of independence and ownership over their inquiry work.

The inquiry components in which few students (below the mean frequency) report that they experienced and developed considerably are locating information sources, using technological aids and a computerized laboratory, building a theoretical model, and teamwork with the rest of the peers. In all these components, few students report considerable difficulty with the performance. This is commensurate with the structure of the intervention in actuality and the observations – the program was built so that the students focused first on the empirical inquiry that required less preliminary knowledge and only in a more advanced stage in the inquiry were the students asked to build a theoretical model for the complex phenomenon. In addition, in light of the observations and according to the students' reports, not all the students used technological aids and a computerized laboratory, and there was no emphasis in the program on teamwork with the rest of the peers in the broader group, except for peer assessment activities that took place at the end of the year. Therefore, the students did not experience much and were not especially challenged and only a few students reported considerable development in these components.

The inquiry components in which only a few students (below the mean frequency) report considerable development despite the considerable experience are choosing a topic, planning an experiment, data processing, and oral reporting on the inquiry. In the component of oral reporting on the inquiry, many students (above the mean frequency) report considerable difficulty in the performance of this component, while in the components of choosing a topic, planning an experiment, and data processing only a few students report that they experienced considerable difficulty.

Regarding the components of choosing a topic and planning an experiment, it is reasonable to assume that in this stage the students received support and direction from the teacher-mentors in these components and therefore did not considerably deal with difficulties associated with these components (such as coping independently with the dynamism found in the inquiry process) and the teacher-mentors even suggested solutions for planning an experiment and gave directions of investigation that provide an answer to the inquiry question and help with the progress of the inquiry.

Regarding the component of data processing, it is reasonable to assume that the students think that they have realized the development in this component already in the previous stages of the inquiry and some of them even feel experts in the skills related to the data processing, and therefore few students reported considerable development or considerable difficulty at this time and there is a significant decline in the percentage of the students from the previous stage. In retrospect, the review of the final presentations of this stage indicates that few students were required by their teacher-mentors to undertake statistical processing of mistakes and comparison between experiment and theory in the boundaries of the error, when these skills can challenge more the students and lead to additional development in this component. In other words, in this aspect the program may set low standards and hence little development.

Regarding the component of oral reporting on the inquiry, in comparison to the previous stage, the preparation stage, indeed the students experienced more the component of oral reporting on the inquiry, and there was even serious experience, which was comprehensive and had greater importance than in the previous stage – the length of time of the presentation was greater, the presentation was a greater scope of the inquiry work, written feedback was given to the students on their work on the part of the teacher-mentors and peers. Furthermore, it is reasonable to assume that the students report considerable experience since the questionnaire was held near to their presentation and preparations towards the presentation gave them a feeling of considerable experience in this component, although in actuality there were not enough opportunities for all the students to experience in this component, aside from the meaningful experience towards the end of the year. Despite the reporting of the students about considerable experience, this component relative to other components in this stage still deviates downwards in development (the

percentage of the students who indicated considerable development in this component is below the mean frequency) and many students (above the mean frequency) report considerable difficulty in the performance of this component. It is reasonable to assume that also in the intermediate stage there was little reference to handling the students' difficulties with standing in front of an audience on the part of the teacher-mentors and therefore the students felt considerable difficulty in this component. In addition, an opportunity was not given to the students to improve their presentation after receiving the feedback and therefore only a few students reported that they developed considerably in this component. Accordingly, in the program it is necessary to provide additional opportunities to the students for experience in the oral reporting on the inquiry during the inquiry work and to provide a time and place for the implementation of the feedback that is given after the presentation.

Regarding the component of the written reporting on the inquiry, many of the students (above the mean frequency) report considerable development in this component (even more than in the previous questionnaire), although few students (below the mean frequency) report considerable experience and considerable difficulty. In this stage, the students are found before the submission of the intermediate report of the project in writing and the students still have not experienced the full writing of an inquiry work and therefore the students have not experienced considerable experience in this component. However, during the year the students were required to document the inquiry work in the research journal (we note that not all the students did so consistently and were meticulous about detailed documentation). In addition, they were required to write a document of intentions in the middle of the year (that includes the description of the inquiry, the goals and direction of the progress of the inquiry) and they were required to write experiment reports in a more structured and fuller manner, unlike in the past; the main reporting was the writing of basic and not full experiment reports for the short activities in the preparation stage, and therefore nevertheless the students felt development in this component.

3.3.3 Stage 3: Final Stage of the Inquiry Project (12th Grade) – Relationship between Development, Experience, and Challenge in the Performance of the Different Inquiry Components (in light of the Observation)

This section presents the processing of the findings of the students' reports on development, experience, and challenges in the performance of the different inquiry components in the final stage of the inquiry project (self-reporting questionnaire before the submission of the summative report, twelfth grade) (from the Summative Questionnaire, see Appendix Number 1.4). The questionnaire was held before the submission of the summative report of the project, in the second half of the twelfth grade, after the students' presentation of the project (May 2019), N=34, when there is a close teacher-mentor for every research team. In this questionnaire the students were asked to choose at least two inquiry components in which in their opinion they gained experience considerably during the inquiry work, at least two inquiry components in which in their opinion they had considerable difficulty during the inquiry work, and at least two inquiry components in which in their opinion they developed greatly during the inquiry work.

3.3.3.1 Stage 3 – Relationship between Development and Experience in the Performance of the Different Inquiry Components

The following figure represents the students' self-reporting on the considerable development/experience in the performance of the inquiry components in the second half of the twelfth grade, N=34, before the submission of the summative report of the inquiry project (from the Summative Questionnaire (repeat)).

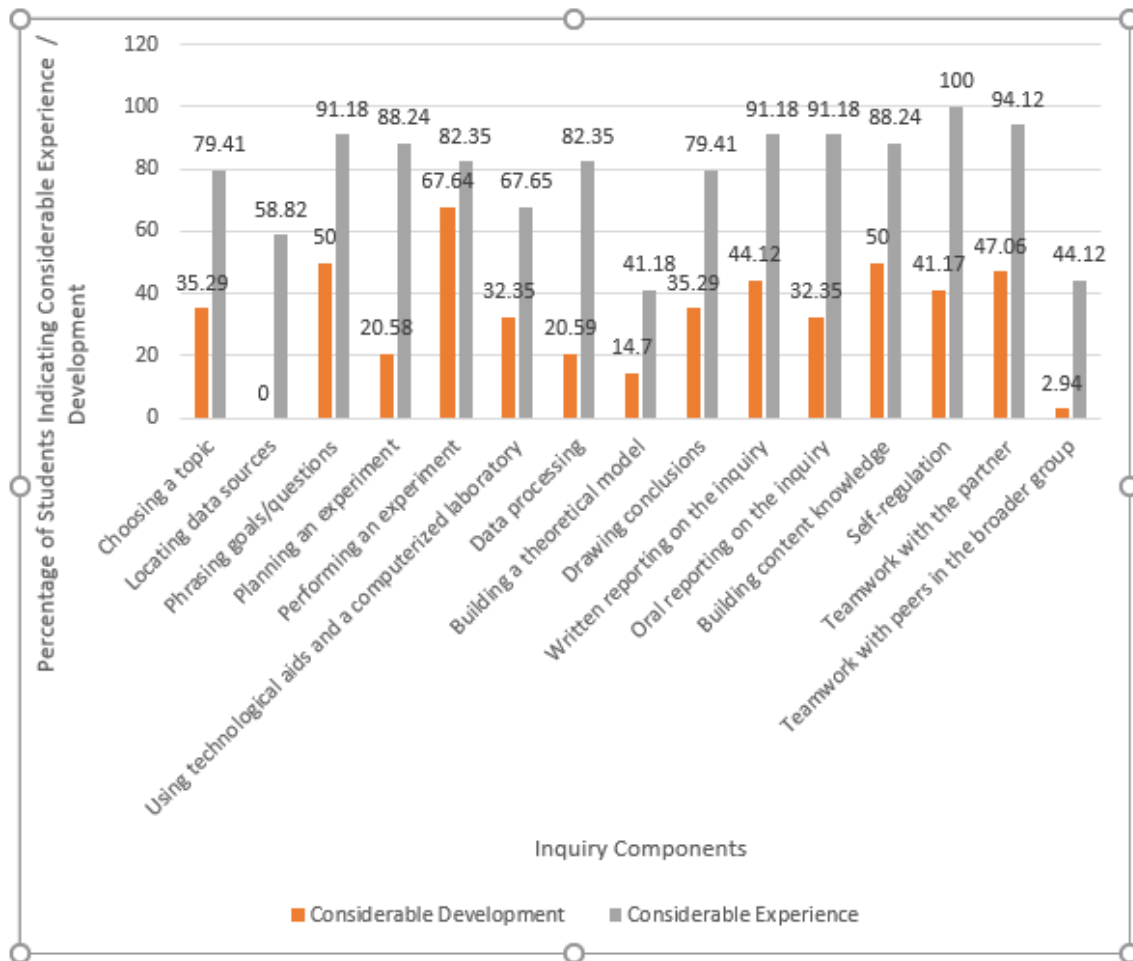


Figure 42: Self-Reporting of Students on the **Considerable Development/Experience** in the Performance of Inquiry Components, 12th Grade (N=34)

To represent clearly the relationship between the development and the experience in the performance of the different inquiry components, mapping was done of the inquiry components that deviate above/below the mean frequency. As will be shown in the following figure 43. The mean frequency is the percentage of the mean indication of all the inquiry components. The mean frequency in this stage regarding development is 33.13%, while the mean frequency regarding experience is 78.62%.

In the following figure, the axes represent the degree of positive or negative deviation from the mean frequency of students who indicated considerable development (Y axis) and considerable experience (X axis) in the different inquiry components. Namely, the origin represents the mean frequency of students who indicated considerable development/experience. The vertical position of the inquiry components represents the

degree of deviation in the aspect of development – as the placement of the inquiry component is higher in the figure, the frequency of the students who indicated considerable development in this component is greater.

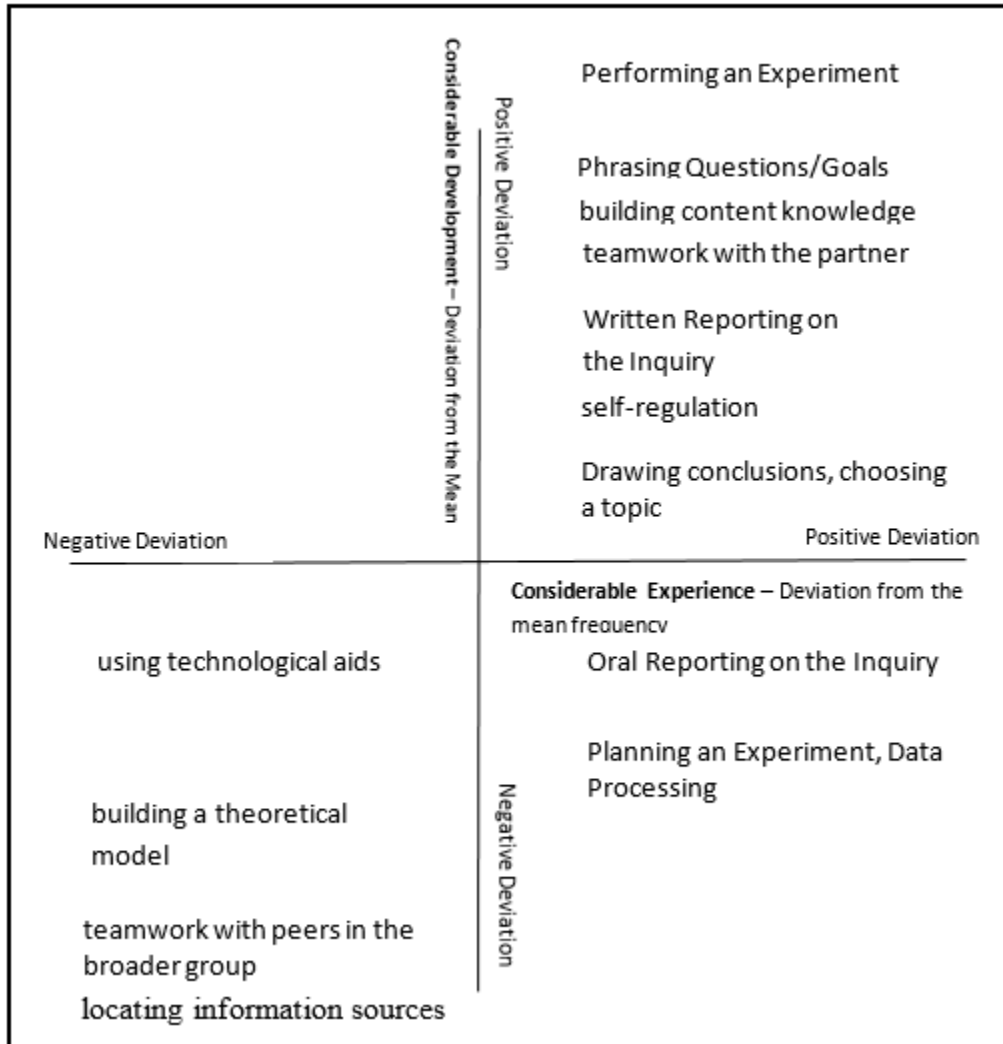


Figure 43: Relationship between **Considerable Development** and **Considerable Experience** in the Performance of the Different Inquiry Components (Representation of the Deviation from the Mean Frequency – Development 33.13%, Experience 78.62%)

12th Grade (N=34) (Sigron, M)

3.3.3.2 Stage 3 – Relationship between Development and Challenges in the Performance of the Different Inquiry Components

The following figure represents the students' self-reporting on the considerable development/difficulty in the performance of the inquiry components in the second half of the 12th grade, N=34, before the submission of the summative report of the inquiry project (from the Summative Questionnaire (repeat)).

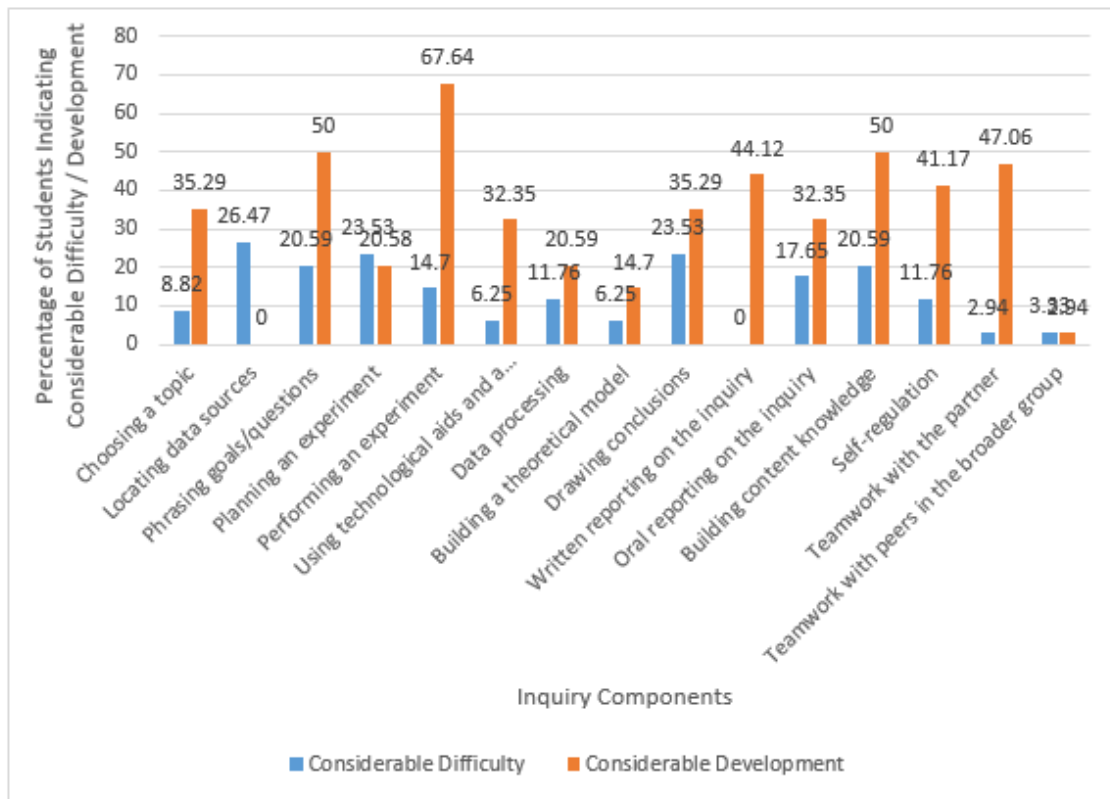


Figure 44: Self-Reporting of the Students on the **Considerable Development/Difficulty** in the Performance of the Inquiry Components, 12th Grade (N=34)

To represent clearly the relationship between the development and the challenge in the performance of the different inquiry components, mapping was performed in the inquiry components that deviate above/below the mean frequency. As will be shown in the following figure 45. The mean frequency is the percentage of indication of all the inquiry components. The mean frequency in this stage regarding development is 33.13%, and the mean frequency regarding difficulty is 13.21%.

In the following figure, the axes represent the degree of positive or negative deviation from the mean frequency of students who indicated considerable development (axis Y) and considerable difficulty (axis X) in the different inquiry components. Namely, the origin represents the mean frequency of the students who indicated considerable development/difficulty. The vertical position of the inquiry components represents the degree of deviation in the aspect of development – as the place of the inquiry component is higher in the figure, the frequency of the students who indicated considerable development in this component is greater.

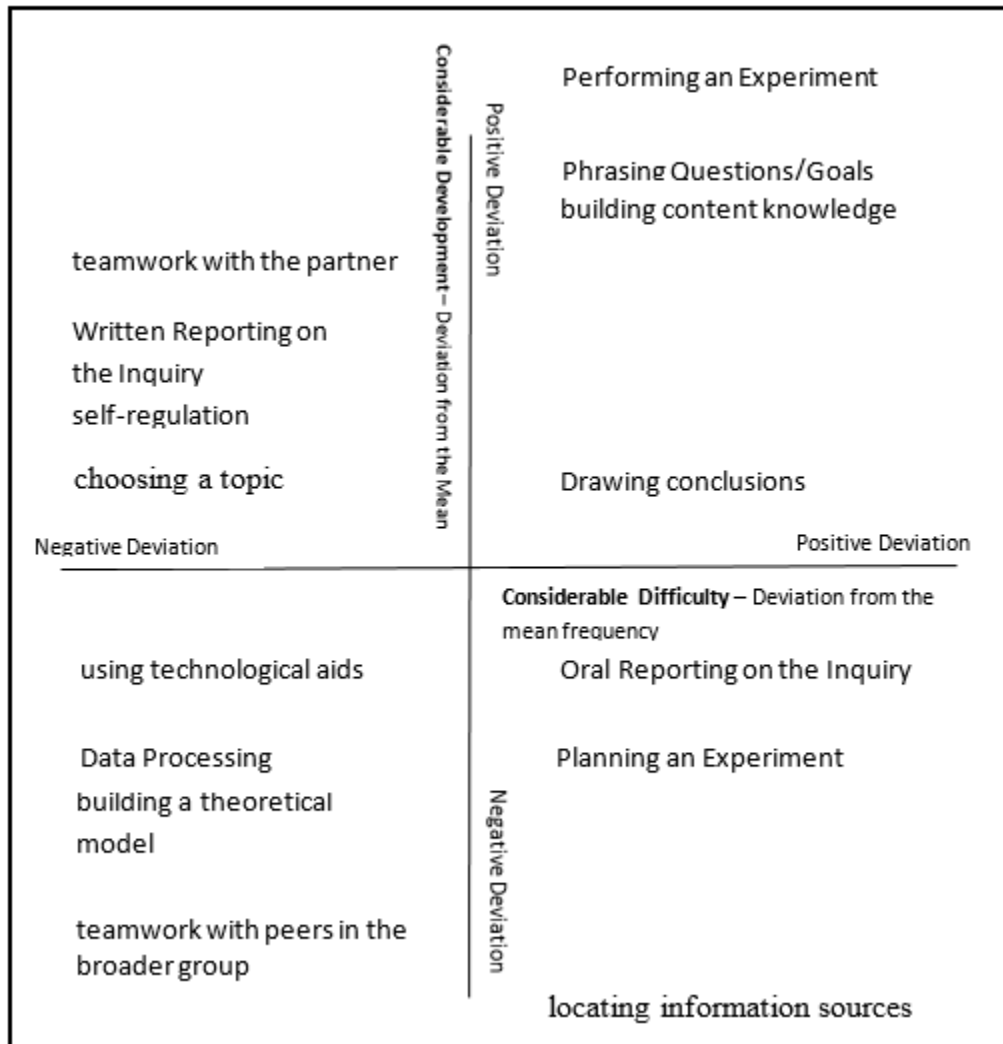


Figure 45: Relationship between **Considerable Development** and **Considerable Difficulty** in the Performance of Different Inquiry Components (Representation of the Deviation from the Mean Frequency – Development 33.13%, Difficulty 13.21%),
12th Grade (N=34) (Sigron, M)

3.3.3.3 Main Findings – The Relationship between Development and Experience and between Development and Challenge in the Performance of the Different Inquiry Components in light of the Observation - Stage 3 (Final Stage of the Inquiry Project)

Following the quantitative analysis and in light of the observation, this subsection will present an interim Summary and discussion of the relationship between development and experience and challenge in the different inquiry components that the students experienced in stage 3, the final stage of the inquiry project (twelfth grade).

The findings from the summative questionnaire (repeat), which was held in the second half of the third year of the program in the twelfth grade (May 2019), were processed. This questionnaire was held towards the end of the project, after the presentation of the students on the summative report of the project. In this year, the inquiry teams engaged in the performance of advanced experiments and in the performance of the planning of new experiments that can provide a response to the inquiry questions that were not fully realized or solve problems that arose during the investigation. In the last phase of this stage, the students engaged primarily in the writing of the summative work, in the organization and classification of their products throughout the entire inquiry process, and preparation towards the reporting on the inquiry in front of an audience. Throughout the entire year, there was close instruction for the entire research team of students.

The following figure presents two figures 43,45 side by side, so that it is possible to clearly see the relationship between development and experience and challenge in the performance of the different inquiry components in stage 3 (the final stage of the inquiry project)

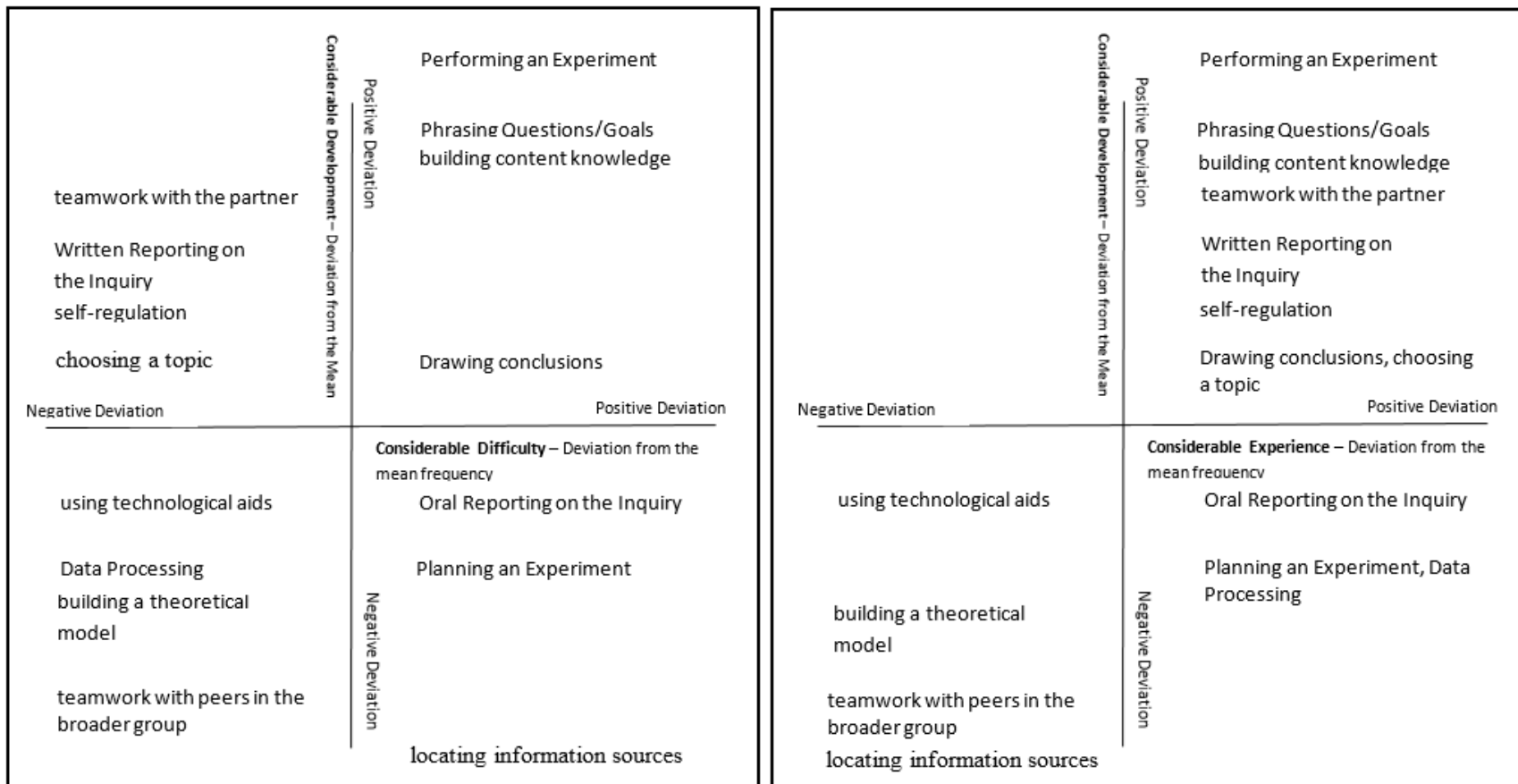


Figure 46: Relationship between **Considerable Development / Considerable Experience/Difficulty** in the Performance of the Different Inquiry Components

(Representation of the Deviation from the Mean Frequency – Development 33.13%, Experience 78.62%, Difficulty 13.21%), Stage 3 – 12th Grade (N=34)

(Sigron, M)

Main Findings of the Above Figures

In the inquiry components of choosing a topic, phrasing questions/goals, performing an experiment, drawing conclusions, written reporting on the inquiry, building content knowledge, self-regulation, and teamwork with the partner, many students (above the mean frequency) report that they experienced and developed considerably. Of these components, it is possible to see that the development is commensurate with the experience and challenge in the inquiry components: phrasing questions/goals, performing an experiment, drawing conclusions, and building content knowledge. In other words, the experience the students report, of considerable experience in these components and considerable coping in challenges that are innate in the performance of these components, is commensurate with the reporting on the considerable development among many students (above the mean frequency).

In other components, self-regulation, teamwork with the partner, written reporting on the inquiry, and choosing a topic, many students (above the mean frequency) report considerable development that is commensurate with reporting on considerable experience. However, it is accompanied by reporting on the lack of challenge.

In the inquiry components of building a theoretical model, using technological aids and a computerized laboratory, and teamwork with the other peers, the students report that they did not experience considerably, were also not especially challenged, and only a few students (below the mean frequency) report considerable development in these components.

In the inquiry components of planning an experiment, data processing, and oral reporting on the inquiry, despite the reporting on the considerable experience, few students (below the mean frequency) report considerable development. (We note that the component of oral reporting on the inquiry is almost equal to the mean frequency.) In the components of oral reporting on the inquiry and planning an experiment, many students (above the mean frequency) report considerable difficulty while in the component of data processing the students were not especially challenged.

In the inquiry component of locating information sources, although many students (above the mean frequency) report considerable difficulty in the performance of this component, not one student (below the mean frequency) reported considerable development in this component.

Description and Discussion on the Findings in light of the Observation

The inquiry components in which many students (above the mean frequency) report that they experienced and developed greatly are choosing a topic, phrasing questions/goals, performing an experiment, drawing conclusions, written reporting on the inquiry, building content knowledge, self-regulation, and teamwork with the partner. This is commensurate with the structure of the intervention in actuality and the observations – in this stage the students decided what to focus on and accordingly they phrased specific inquiry questions/goals. The students carried out advanced experiments and drew conclusions and in parallel learn the relevant theory for the increase of the depth of the investigation and the understanding of the researched phenomenon. Throughout this stage, the students coped with the dynamism of the inquiry and encountered situations of lack of certainty, and to overcome these situations they performed re-thinking of the choice of directions of investigation, improved the teamwork and their self-regulation. In addition, throughout the entire time the students documented the inquiry process, and towards the end of the process emphasis was placed on writing the final work. It is reasonable to assume that the considerable experience contributed to the development in these inquiry components.

Among these inquiry components include phrasing questions/goals, drawing conclusions, and building content knowledge (like in the previous questionnaire, in the intermediate stage) and in addition also the component of performing an experiment, many students (above the mean frequencies in all the inquiry components) even report considerable difficulty in performing these components, which is commensurate with the report on the considerable development. Indeed, in this stage the students focused the inquiry question, coped with building the experiment system and improving it constantly, in order to obtain more accurate measurements. Moreover, in this stage the students displayed more independence and initiative than in the past in the performance of experiments and in the providing of a solution to the problems that arose in the experiment system and therefore the percentage of students that indicated considerable difficulty in the component of performing an experiment increased compared to the previous stage. In addition, the students compared the results to the theory, so as to reach correct conclusions and furthered the depth of the understanding and knowledge about the researched phenomenon. It is reasonable to assume that the experience and challenge in these components contributed to the students' development in these components.

In other components, self-regulation, teamwork with the partner (like in the previous questionnaire) and also choosing a topic and written reporting on the inquiry, many students (above the mean frequency) experienced considerable experience, but few students experienced considerable difficulty in the performance of these components and nevertheless many students reported considerable development. It is reasonable to assume that the very experience was enough to enable development in these components. In addition, it is reasonable to assume that the close instruction contributed to the students' development in these components.

Regarding the component of self-regulation, indeed in this stage the students manage their inquiry work more independently than in the past, try to meet the time schedule and the planning of the work they set for themselves, and have greater initiative and independence in the performance of the inquiry work. For instance, it is possible to see at the start of the encounter that the students independently access the equipment they need, build the experiment system according to their planning that they had ahead of time, solve independently problems that arose during the investigation, make intelligent decisions primarily in situations of uncertainty, and bring up solutions and ideas for the continuation of the work. In addition, it is possible to see the research staffs examining their findings and conclusions, writing and organizing the written work of the research independently, planning the structure of the work, and forming the way to present their new knowledge in a convincing manner.

Regarding the component of teamwork with the partner, from the observations it was possible to see that students respond positively to explanations of their partner to the project (without fear of judgment), are attentive to their statements, and are open to new and different ideas. In addition, their teamwork is expressed in shared learning of the theory relevant to their inquiry and the practical ways of investigation. Regarding the observation, it was possible to see that there was the division of the work and the division of the roles between the partners. In most of the teams, the division was clear between the students, when each one in the team engaged in a field in which he felt that he has mastered, and in the end there was the sharing of the findings and the products with the peers in the team. Sometimes the collaborative learning resulted in creativity among the students to solve problems that came up during the inquiry work, using brainstorming to solve problems and development of ideas into directions of investigation, and it would appear that they enjoyed working together.

Regarding the component of choosing a topic, indeed in this stage the students more coped with the choice of the directions of investigation and focus of the researched topic and therefore more students experienced considerable development than in the previous stage.

Regarding the component of written reporting on the inquiry, indeed the students considerably experienced in this stage more than in the previous stage, they took greater pains about documenting the inquiry, and they had more experience in the writing of the laboratory reports (both in their scope and in the improvement of their quality) and are found towards the writing of the summative report. In the qualitative analysis of this stage, it was possible to see that the students experienced a certain difficulty (although not great) in this component, the students described a not insignificant number of difficulties related to this component, and they tell that the meticulous documenting of the inquiry, as well as the teacher-mentors' providing feedback on the written work made it easier for them in the writing of the summative report of the project.

In addition, in light of the observation, sometimes the close teacher-mentor provided support and direction of the choice of the research direction, especially when they reached situations of uncertainty, division of work between the partners, setting time schedule, and encouragement to meet it (primarily towards the end of the project), which eased to a certain degree the students' difficulty with the performance of these components, while trying not to harm the students' independence in the performance of the inquiry and the leading of the inquiry project.

Inquiry components in which few students (below the mean frequency) report they experienced and developed considerably in the inquiry component are using technological aids and a computerized laboratory, building a theoretical model, and teamwork with the other peers. In all these components few students report considerable difficulty with their performance (like in the previous questionnaire, in the intermediate stage). Regarding the component of using technological aids and a computerized laboratory, the value is under the mean frequency but is almost equal to the mean frequency, and indeed half of the students used the computerized laboratory and technological instruments and it is reasonable to assume that some of them experienced and developed considerably. Regarding the component of building a theoretical model and teamwork with the rest of the peers, in the final stage of the project in the end emphasis was not placed on building a theoretical model and only a few

students (below the mean frequency) did this. In addition, emphasis was not placed in the program on the creation of many interactions between the rest of the peers in the broader group and peer assessment was not performed in an orderly and continuous manner.

The inquiry components in which only a few students (below the mean frequency) report considerable development despite the considerable experience are planning an experiment, data processing, and oral reporting on the inquiry. We note that the component of oral reporting on the inquiry is almost equal to the mean frequency in this aspect, when in the component of oral reporting on the inquiry many students (above the mean frequency) report considerable difficult (like in the previous questionnaire). In addition, many students report this in the component of the planning of an experiment while in the component of data processing only a few students report considerable difficulty (like in the previous questionnaire).

Regarding the component of planning an experiment, indeed in this stage the students more experienced and coped with difficulties related to the component of planning an experiment than in the previous stage, like planning a better experiment system, isolating variables better in order to reduce the factors of error and obtain more accurate measurements, and finding solutions to the problems that appears during the work process. It is reasonable to assume that the enabling of the students in this stage to be more independent than in the past led to challenge in this component. Nevertheless, this coping still did not provide considerable development in this component in many students.

Regarding the component of data processing, it is reasonable to assume that the students realized the development in this component already in the early stages of the inquiry and even felt that they are almost experts in the performance of this component (both in the quality of the performance and in the speed of the performance of this component). Therefore, only a few students reported considerable difficulty and felt development to a great extent. The observations and from the review of the students' written work indicate that few students addressed the statistical analysis of the distribution of the findings and the finding of the value of uncertainty in the measurement (and some are not even aware of its existence). The students addressed more the relative error of the results of the experiment from the theoretical value and described the factors of mistake (most of the students did not examine whether the relative error is found in the range of

error of uncertainty). In retrospect, it was possible to develop further this component and to require of the students statistical processing of errors and comparison between experiment and theory in the boundaries of the error.

Regarding the component of oral reporting on the inquiry, despite the reporting of the students on the considerable experience in this component, the students still experience considerable difficulty in this component. In retrospect, it was possible to develop further this component and to give greater preparation and opportunity for experience in the oral presentation during the inquiry work and not only at the end and to provide tools to overcome the difficulties related to this component. We note that although the component of oral reporting on the inquiry is found in the figure under the mean frequency in the aspect of development it is very close to the mean and there is even an increase in the percentage of students who indicated considerable development relative to the previous stage, the intermediate stage.

We note the component of locating information sources in which a student did not indicate considerable development, despite the reporting on considerable challenge (even much more than in the previous questionnaire). In addition, few students reported considerable experience in this component. The students' responses in the open questions indicate that the most prominent difficulty in this component is finding a low number of information sources relevant to the researched topic, primarily when the researched phenomenon is not common. In addition, the difficulty derives from the low experience in this component. In light of the observation, most of the teacher-mentors proposed information sources relevant to the students' inquiry; however, they did not give the students the tools for overcoming difficulties related to this component. For the most part, the students were content with the sources they received from the teacher-mentors. Therefore, the students experienced considerable difficulty with the locating of new sources and there was no significant development in this component. In retrospect, it was possible to add activities that engage in the component of locating information sources already in the stage of the preparation (in the first year of the program) and during the work on the inquiry project, in order to give the students more opportunities to acquire this skill. In addition, the teacher-mentors must give more tools to students for coping with difficulties entailed by this component.

3.3.4 overall picture of the Relationship between the Development, Experience, and Challenges in the Performance of the Different Inquiry Components throughout the 3 Stages of the Program

The aim of this subchapter is to reflect in a look from above the changes that occur in the relationship between the development, experience, and challenge that the students experienced in the performance of the different inquiry components throughout all the stages of Research Physics Program, on the basis of the representations of the relationship in each and every stage separately (it is possible to see the details in every stage separately in the previous subchapters 3.3.1 – the preparation stage (N=27), 3.3.2 – the intermediate stage (N=33), and 3.3.3 the final stage (N=34) of the inquiry work).

It should be noted that the research assumption was that the degree of experience or degree of challenge that the students experience in the inquiry components in the program will influence the students' degree of development in these components. In particular, as the students will experience inquiry components in the program and will cope with the challenges innate in their performance, the development will be more significant. The research assumption was realized only for some of the inquiry components, as seen below, when groups 1-3 tend to be closer to the assumption, while group 4 is not commensurate with it.

The findings will be presented regarding four groups of inquiry components, which are different in the program that describes the relationship between development, experience, and challenge during the inquiry work in the Research Physics Program:

Group 1 Significant development is commensurate with a considerable degree of experience and challenge.

Figures 47, 48 and 49 present, respectively, the experience, challenge, and development in the inquiry components – "**phrasing questions/goals**", "**drawing conclusions**", and "**building content knowledge**". (These figures are based on the representations of the relationship in each and every stage separately that are presented in the previous chapters 3.1, 3.2, 3.3.)

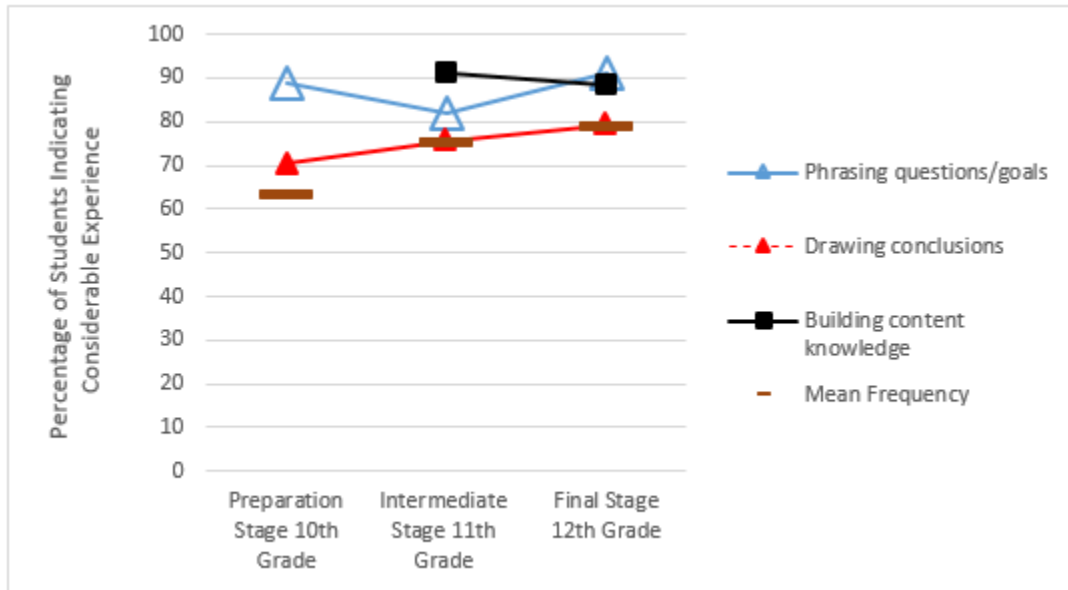


Figure 47. Report of Students on the **Considerable Experience** in the Performance of the Inquiry Components of **Group 1** in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)

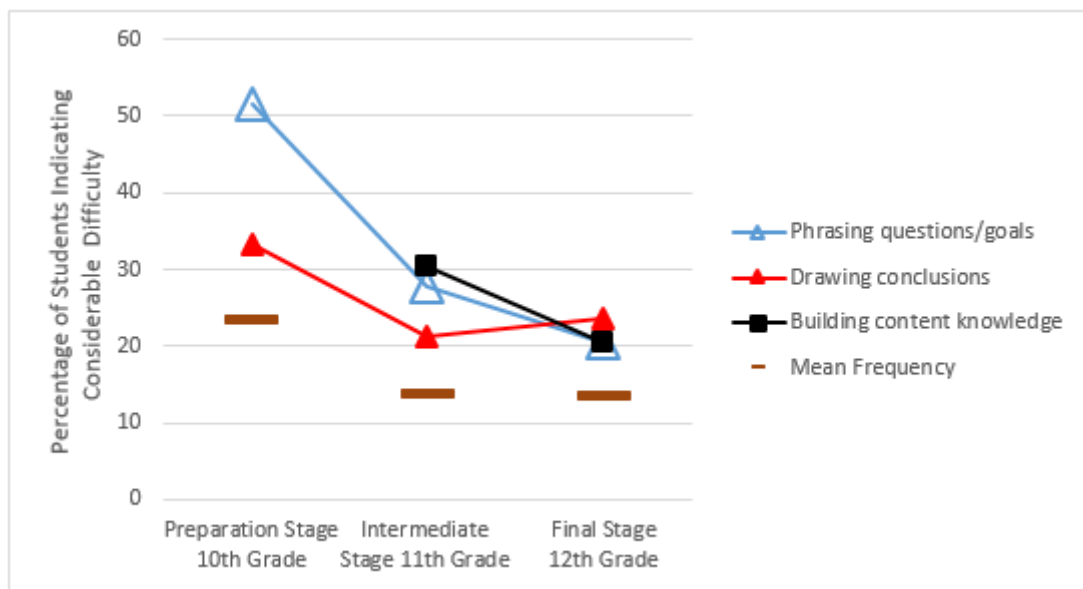


Figure 48: Report of Students on the **Considerable Difficulty** in the Performance of the Inquiry Components of **Group 1** in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)

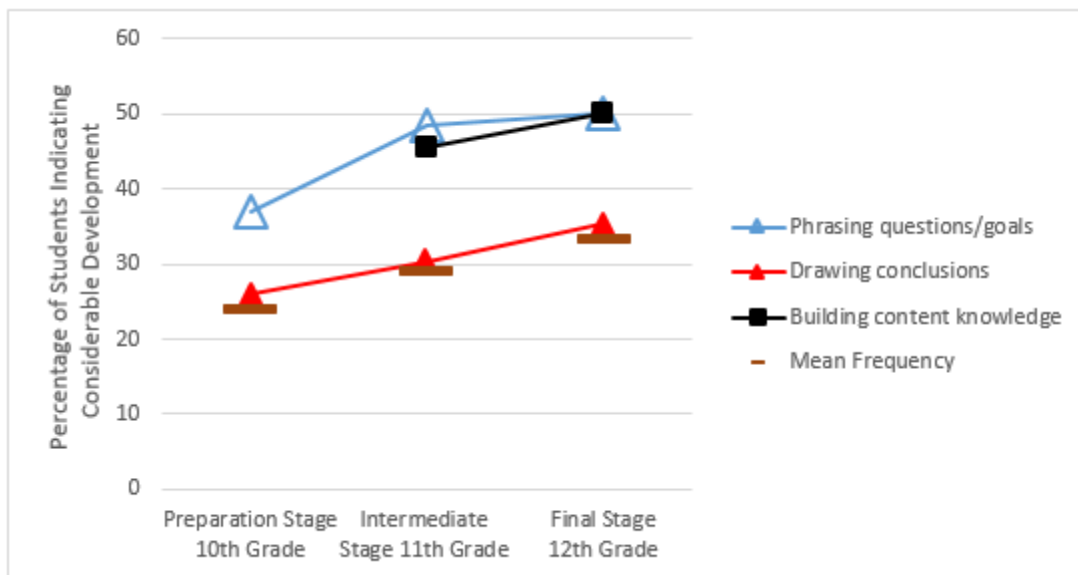


Figure 49: Report of Students on the **Considerable Development** in the Performance of the Inquiry Components of **Group 1** in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)

It is possible to see from the above figures that in the inquiry components of group 1 – phrasing questions/goals, drawing conclusions, and building content knowledge, in most of the stages of the program the percentage of the students who indicated considerable experience, considerable difficulty, and considerable development is greater than the mean frequency of all the components. In addition, it is possible to see that the difficulty steadily lessens throughout the inquiry stages, but still many students (above the mean frequency) reported considerable difficulty in these components. Namely, meaningful development is commensurate with a considerable degree of experience and challenge in the performance of these components.

Group 2 Significant development is commensurate with a considerable degree of experience, while the challenge is low

Figures 50, 51 and 52 present respectively the experience, challenge, and development in the inquiry components – "**choosing an experiment**", "**performing an experiment**", "**written reporting on the inquiry**", "**self-regulation**", and "**teamwork with the partner**". (These figures are based on the representations of the relationship in each and every stage separately that are presented in the previous chapters 3.1, 3.2, 3.3.)

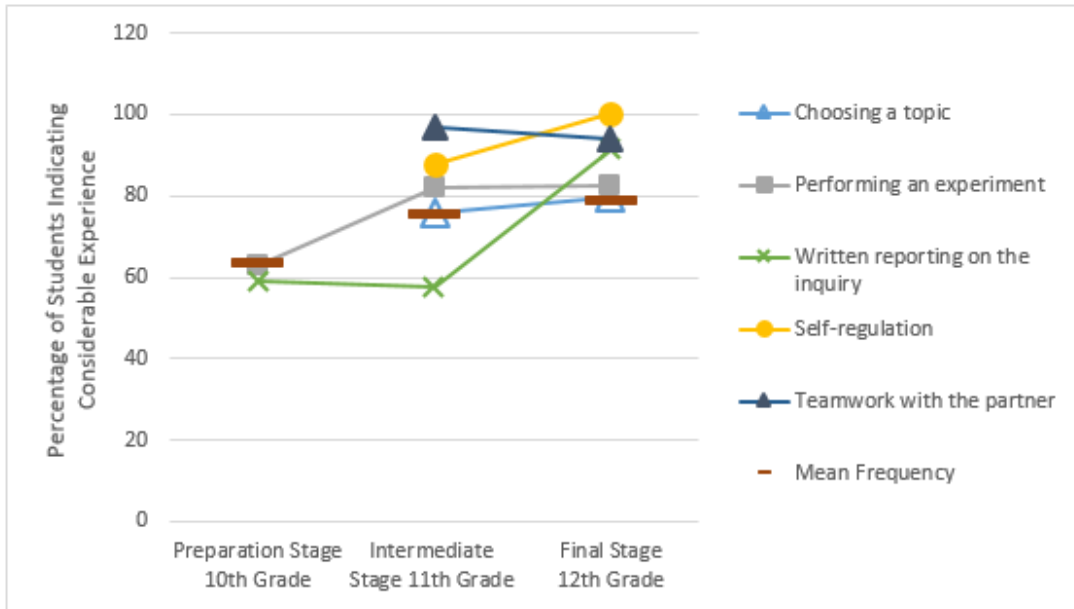


Figure 50: Reporting of Students on the **Considerable Experience** in the Performance of the Inquiry Components of **Group 2** in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)

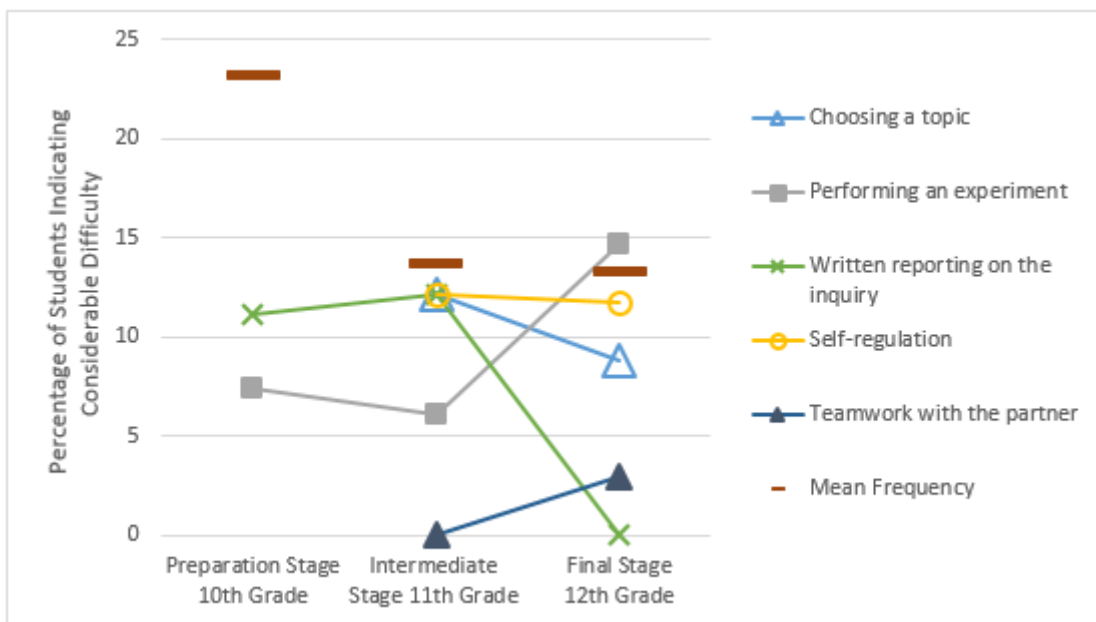


Figure 51: Reporting of Students on the **Considerable Difficulty** in the Performance of the Inquiry Components of **Group 2** in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)

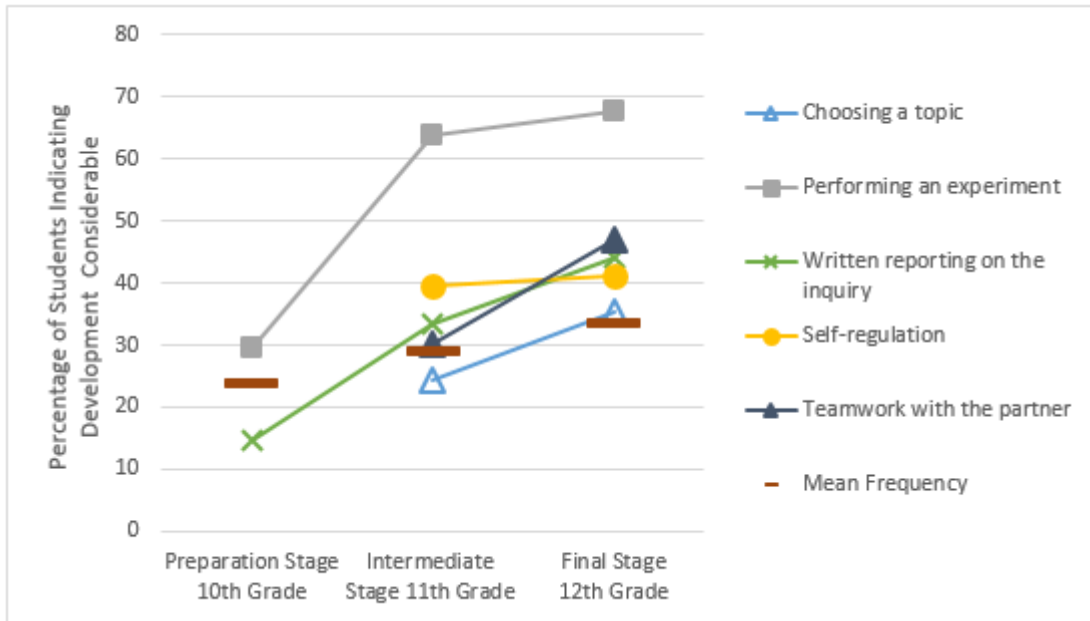


Figure 52: Reporting of Students on the **Considerable Development** in the Performance of the Inquiry Components of **Group 2** in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)

It is possible to see from the above graphs in the inquiry components of group 2 - performing an experiment, self-regulation, teamwork with the partner, in most of the stages of the program the percentage of the students who indicated considerable experience and considerable development is greater than the mean frequency of all the components. However, the percentage of the students who indicated considerable difficulty is lower than the mean frequency. It is possible to see this also in the component of the written reporting on the inquiry and in the component of choosing a topic only in the final stage of the inquiry process. In other words, the very considerable experience alone was enough to allow the students significant development in these components. The significant development in these components is commensurate with a considerable degree of experience, even while the challenge is low.

Group 3 Low development is commensurate with a low degree of experience
(even if there is considerable or low challenge)

Figures 53,54 and 55 present respectively the experience, challenge, and development in the inquiry components – "**locating information sources**", "**using technological aids and a computerized laboratory**", "**building a theoretical model**", and "**teamwork with the other peers**". (These figures are based on the representations of the relationship in each and every stage separately that are presented in the chapters 3.1, 3.2, 3.3.)

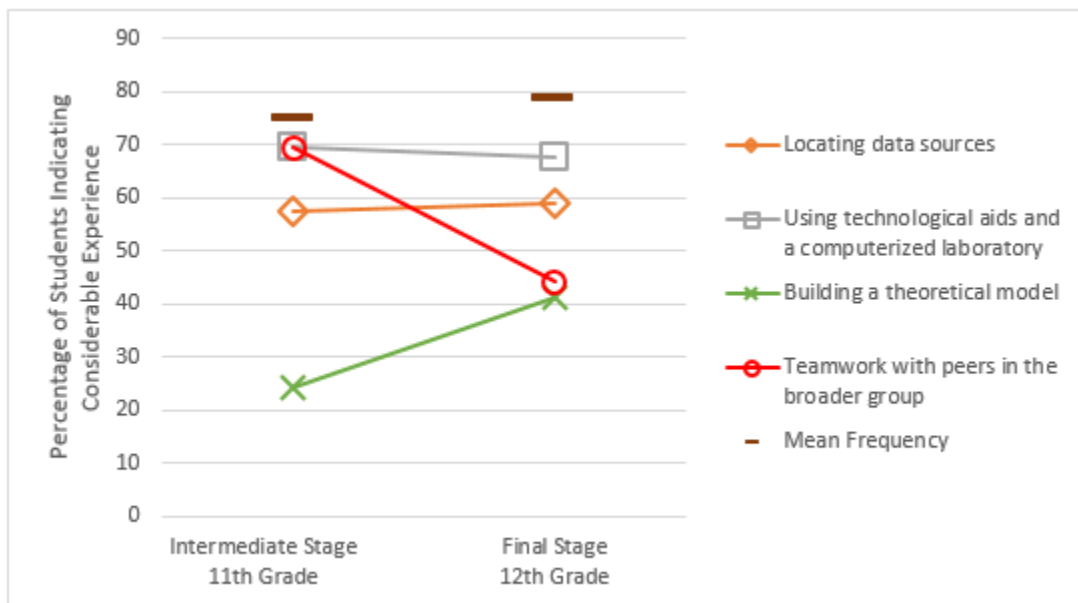


Figure 53: Reporting of Students on the **Considerable Experience** in the Performance of the Inquiry Components of **Group 3** in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)

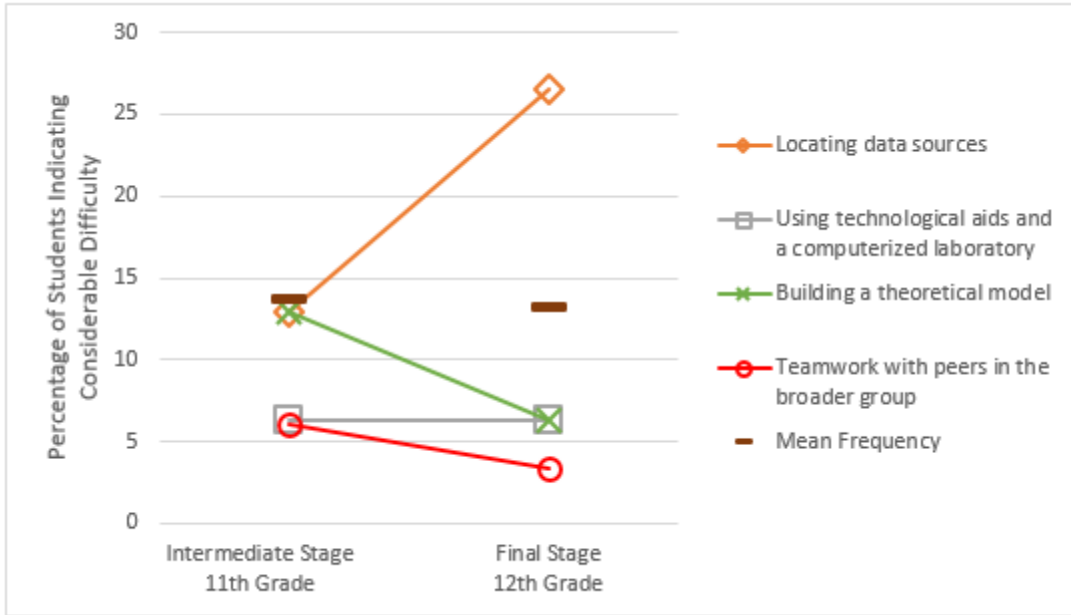


Figure 54: Reporting of Students on the **Considerable Difficulty** in the Performance of the Inquiry Components of **Group 3** in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)

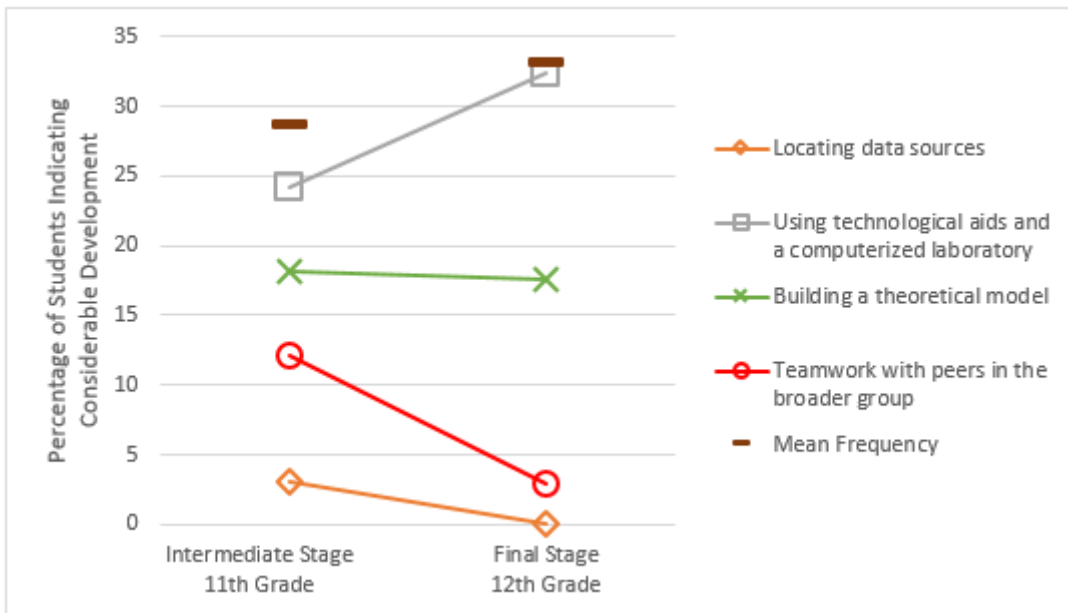


Figure 55: Reporting of Students on the **Considerable Development** in the Performance of the Inquiry Components of **Group 3** in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)

It is possible to see from these graphs in the inquiry components of group 3, using technological aids and a computerized laboratory, building a theoretical model, and teamwork with the rest of the peers, in most of the stages of the program that the percentage of the students who indicated considerable experience, considerable difficulty, and considerable development is less than the mean frequency of all the components. In other words, the students did not experience and were not challenged greatly in most of the inquiry process and only a few students reported considerable development in these components. In addition, in the component of locating information sources, the lack of experience, even if there is great challenge in the final stage of the inquiry, did not lead to significant development among the students in the ability of performance of this component. In other words, low development is commensurate with a low degree of experience (even if there is great or poor challenge).

Group 4 Low development despite the considerable degree of practice (even if there is considerable or low challenge)

Figures 56, 57 and 58 present, respectively, the experience, challenge, and development in the inquiry components – "**planning an experiment**", "**data processing**", and "**oral reporting on the inquiry**". (These figures are based on the representations of the relationship in each and every stage separately that are presented in the previous s chapters 3.1, 3.2, 3.3.)

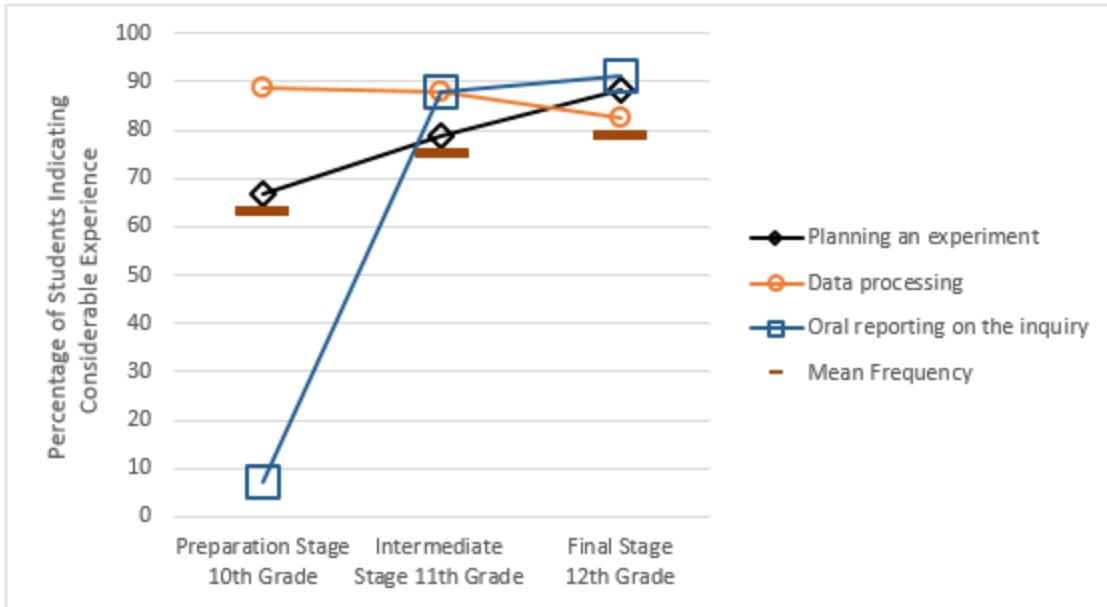


Figure 56: Reporting of Students on the **Considerable Experience** in the Performance of the Inquiry Components of **Group 4** in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)

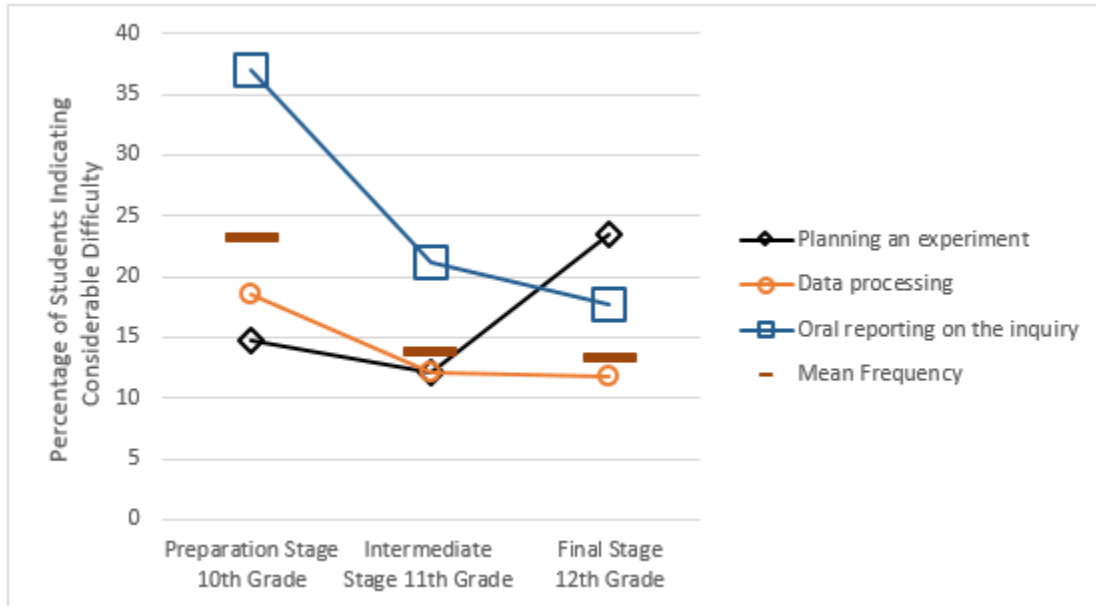


Figure 57: Reporting of Students on the **Considerable Difficulty** in the Performance of the Inquiry Components of **Group 4** in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)

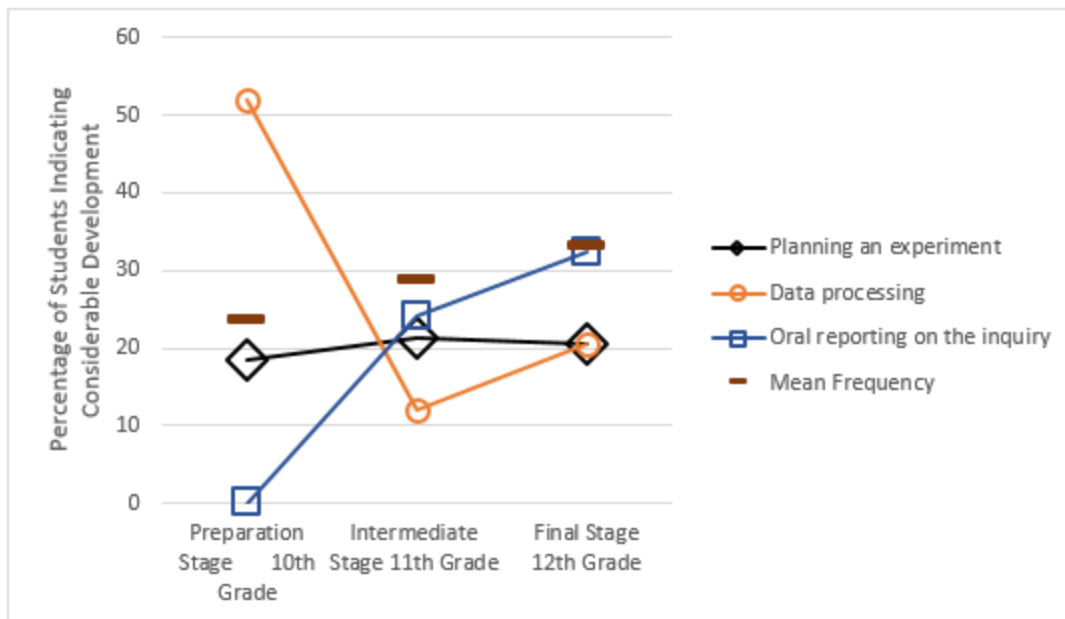


Figure 58: Reporting of Students on the **Considerable Development** in the Performance of the Inquiry Components of **Group 4** in the Inquiry Stages: Preparation Stage (N=27), Intermediate Stage (N=33), and Final Stage (N=34)

It is possible to see from the aforementioned graphs that in the inquiry components of group 4, planning an experiment, processing data, and oral reporting on the inquiry, in most of the stages of the program the percentage of the students who indicated considerable experience is greater than the mean frequency of all the components. However, the percentage of the students who indicated considerable development is lower than the mean frequency. In addition, it is possible to see in the component of oral reporting on the inquiry in the intermediate stage and final stage and in the component of planning an experiment, in the final stage of the inquiry, even when the students reported considerable difficulty, few students (under the mean frequency) experienced significant development in this component. In other words, unlike what is expected, despite the considerable experience throughout most of the inquiry work there was little development in the students' ability to perform these components throughout most of the inquiry stages (whether there is great or little challenge).

Overall picture, four groups of inquiry components were found, which are different in the track that describes the relationship between development, experience, and challenge during the inquiry work in the ‘Research Physics’ program. As noted previously, of the four groups, there is one group, group number 4, which deviates from the initial assumption. In this group there are inquiry components in which the students’ development was sparse, although the students experienced greatly in these components during most of the program stages when in the other groups 1-3 there is greater tendency towards the assumption.

1. Inquiry components in which the development is significant and is commensurate with a considerable degree of experience and challenge: phrasing questions/goals, drawing conclusions, and building content knowledge.

Indeed, the program obligated the students to refine and focus the research questions throughout all the program stages, to provide a repeated response to gaps between the experiment findings and the theory, through independent learning of the complex theoretical material. The coping with these components is perceived by the students as especially challenging. It is based on the one hand and developed on the other hand character traits of curiosity, desire to succeed, perseverance, responsibility, openness, and joint learning ability with the project partner. Alongside this, in these components considerable support from the teacher-mentors was required, on the one hand, support of entertaining thinking – critical examination of the intermediate products, which broadens the reference to a range of aspects in the researched phenomenon, and on the other hand, focused assistance – the identification of information sources relevant to the researched topic and explanation of things that are not understood or are complex for the students.

2. Significant development is commensurate with a considerable degree of experience, while the challenge is sparse: performing an experiment, self-regulation, and teamwork with the partner, written reporting on the research, and choosing a topic.

Indeed, the program offered the students an experience that became more complex, ranging from simple exploratory experiments in the beginning to coping with building a steadily more complex and sophisticated experiment system and to advance more precise measurements. This obligated self-regulation in aspects of planning and organization of the inquiry work, meeting a time schedule given other school commitments, intelligent decisions in situations of uncertainty, and coping with concomitant frustrations. In addition, this

obligated the division of roles between the team members in order to increase the work effectiveness. The students noted that they were supported by the laboratory technician who placed at their disposal considerable equipment and helped install it, and the teacher-mentors – the follow up and formative assessment of the planning and progress in the work. They perceived their seriousness, responsibility, dedication, and creativity, as individuals and in the research team, as at the basis of their success in managing the inquiry from its beginning to its end. Namely, the very experience in these components led to a improvement of the quality of the experiment system and the development of practices of management of the inquiry work and teamwork, such as the development of interpersonal skills ranging from consideration of others' constraints and support in a time of crisis or frustration to joint thinking and problem solving. It is possible to hypothesize that the reporting on limited challenges is related to the feeling of self-efficacy in providing an answer to problems that arise along the way and the ownership and enjoyment deriving from it.

In the component of written reporting on the inquiry and choosing the topic the picture is a little different. According to the students' reports, which describe things as they undergo them, these two are characterized by the fact that in the preparation stage and in the intermediate stage of the inquiry work a significant experience or challenge was not provided. Conversely, in the final stage the challenge intensified – written reports were required in different configurations, from documenting an inquiry journal to writing the summative work, and it is necessary to re-think the investigation directions and to implement consideration of what to focus on. Despite the relatively low ranking of difficulty in these components, the students described difficulties both in written reporting – in their ability to persevere in the documenting of the inquiry and in the summarization of the main points and in the choosing the topic – to define the most productive topic and to focus on it. The development is expressed mainly in the final stage of the inquiry work in organized writing, which is more concise, understood, and clear. The students experienced support and direction on the part of the teacher-mentors with which they developed in their ability to differentiate between what is important and what is less so and to make decisions on the focusing of the topic and the writing of the work. Here too, it is reasonable to assume that the reporting on the limited challenge is related to the fact that this support was enough to enable the students to advance significantly in these components.

3. Sparse development is commensurate with a slight degree of experience (even if there is great or sparse challenge): locating information sources, using technological aids and a computerized laboratory, building a theoretical model, and teamwork with the rest of the peers.

This group of components reflects the observation that indeed students engaged in a limited manner in the above components, and emphasis was not placed on building a theoretical model except in the subgroup that engaged in the building of a theoretical model using computational modeling. In the component of teamwork with the peers in the broad group, the students did not have considerable experience and there was even a significant decline in the percentage of students indicating considerable experience from the intermediate stage to the final stage of the inquiry process. While in the intermediate stage there was a framework of presentation to the peers and peer assessment, as a rule peer assessments were not held in an ongoing and regular manner. The students who do report this component indicated the importance of the teamwork with the peers in the broad group and particularly performing peer assessment, which provides them with proposals for the improvement of the work and proposals for the continuation of the investigation, provides them with satisfaction and confidence in their work and their presentation, and exposes them to other researches of their peers.

4. Sparse development despite a considerable degree of experience (even if there is great or sparse challenge): planning an experiment, data processing, and oral reporting on the inquiry.

Regarding the experience, indeed, corresponding to the structure of the program and in the mirror of the observation, there was considerable experience in these three components in most of the inquiry stages. In the aspect of the planning – the inquiry project obligated repeated engagement in the planning of the experiment. In the aspect of the data processing – already in the preparation stage the students were exposed to the different instruments for data processing and implemented them in the continuation. In the aspect of the oral presentation, the program integrated an oral presentation in the early stages of the inquiry. Regarding the challenge, the picture was changed to different components. In the aspect of the planning – only in the final stage when they had to improve the planning in order to provide a response to the problems arising in the early stages of the project. In the aspect of the data processing there is difficulty

only in the preparation stage, when they were first exposed to the tools of the data processing, and in the oral presentation they report great challenge in all the stages – to convey the thought into oral expression, to master the knowledge at the time of the presentation, to deal with the anxiety of audiences. Accordingly, the explanation of the feeling of limited development among the students is different for each and every one of the components.

For the component of planning, the observation indicates that the students were required to present a work plan a number of times and were even instructed what are the components required in the program. The feedback on the planning existed according to the opinion of each and every teacher-mentor, without shared patterns, when some of the teacher-mentors even propose solutions of planning for the students. The program did not engage explicitly in the tools for planning, for example understood strategies for the solving of problems. Accordingly, it is reasonable to assume that the students did not recognize this component as a significant component, and some of them did not cope with it independently.

Regarding the component of data processing, a main challenge in the data processing in a scientific project is the explanation of the gaps between theory and experiment in the bounds of measurement errors through instruments of statistical analysis – evaluation of the uncertainty in measurements. In actuality, the observation indicates that the analysis tools were similar largely to those used in the school physics laboratory and the students did not make use enough of more advanced statistical analysis tools, so that this component did not challenge the students beyond the standards to which they were exposed first at the start of the program, in parallel to their entry into the program in the school.

Regarding the component of oral reporting on the inquiry in the mirror of the observation, the challenging experience was in the advanced stages of the inquiry, towards the submission of the intermediate project (the end of the eleventh grade) and towards the submission of the final project (the end of the twelfth grade), where they had to reflect a long term inquiry process and handle the regular criticism of their peers and teacher-mentors. The support of the teacher-mentors towards the oral presentation was according to each and every teacher-mentor's opinion. The program did not explicitly engage in tools for oral presentation. After the presentation of the intermediate and summative reports, the students were asked to improve their presentations but there was not another presentation that provides an opportunity to improve their performances.

3.4 Comprehensive Summary of the Findings for the First Research Question

This chapter presents a comprehensive summary of the findings that provide an answer to the first research question:

- 1) How did students' perception of their development relate to their perception of the experience and challenge in performing various inquiry components²⁵ along the stages²⁶ of the 'Research Physics' Program?

In particular:

- A) Students' perception of their **experience and challenge** in each stage of the program:
 - To what extent did students experience each of the inquiry components?
 - To what extent did students find these components to be challenging for them?
 - What are the challenges that students identify they have faced and what means did they use to cope with them?
- B) Students' perception of their **development** in each stage of the program:
 - To what extent did students develop in each of the inquiry components?
 - What aspects of the inquiry components do student believe that they have developed and what are the causes for this development?
- C) **Students' development, following experience and challenge** in each stage of the program:
 - How did the extent of the students' development in the various inquiry components relate to the extent of experience and challenge in these components?
 - How do the experiences, challenges, and development, as perceived by the students, correspond to the observed experiences, challenges and development?

The detailed findings are presented in chapter 3: part A in chapter 3.1, part B in chapter 3.2, and part C in chapter 3.3.

²⁵ In 15 components of inquiry: Choosing a topic, Locating data sources, Phrasing goals/questions, Planning an experiment, Performing an experiment, Using technological aids and a computerized laboratory, Data processing, Building a theoretical model, Drawing conclusions, Written reporting on the inquiry, Oral reporting on the inquiry, Building content knowledge, Self-regulation, Teamwork with the partner, Teamwork with peers in the broader group.

²⁶ Stages of the program: a preparation stage for the inquiry project, an intermediate stage and a final stage of inquiry work (see chapter 1.2.4.3- Intervention Structure of the "Research Physics" Program)

The objective of this chapter is to summarize the experience, challenge, and development that the students experienced in the ‘Research Physics’ program and to present the relationship between development, experience, and challenge in the performance of the different inquiry components in the different stages in the program (preparation stage, intermediate stage, and final stage of the inquiry work), on the basis of the students’ self-reports²⁷, the researcher’s observations of the work of the teams of students, and the conversations with the program designers (a description of the findings in chapters 3.1, 3.2, and 3.3). In addition, the chapter presents possible recommendations for the design of a ‘Research Physics’ Program framework.

It should be mentioned that the research assumption was that the degree of experience or degree of challenge that the students experience in the inquiry components in the program will influence the students’ degree of development in these components. In particular, as the students experience the inquiry components in the program and cope with challenges entailed by the performance of the components, the development will be more meaningful.

It is possible to see that the inquiry process for the long term is meaningful and helps the assimilation of the practices acquired in the performance of the different inquiry components (in most of the inquiry components there was an increase from the stage of preparation to the final stage of the inquiry work for a number of students who indicated considerable development). The students’ descriptions of the aspects of development in the different inquiry components, also in components in which few students reported considerable development (see chapter 3.2) and difficulties and ways of coping in the performance of every component (see chapter 3.1), indicate that the inquiry activities brought about significant development when the students are more involved and independent in their performance, when they are allowed to deal with the challenges entailed by the different inquiry components, when the students use creative and critical thinking to overcome these challenges, and when the student is committed to responsibility, initiative, and ownership of the work. In parallel, they need the teacher-mentors who on

²⁷ Students' answers in quantitative and qualitative questionnaires instruments: Preliminary questionnaire (N=33), Inquiry skills questionnaire (N=27), Summative Questionnaire (N=34), Observation of the students' activities

the one hand will push for depth and on the other hand will provide a safety network for dealing with the difficulties posed by the inquiry. The students praise the teamwork with the partner as one of the main factors that helped them develop in the various components of the research and as one of the ways of coping with difficulties they experienced during the performance of the inquiry. Moreover, the students note the importance of a learning environment that gives the resources that enable the inquiry to be performed (such as access to a wide variety of laboratory equipment and technological instruments, laboratory assistants who are at their disposal and offer help with building different experiment systems) as essential to their development at the time of the inquiry work.

Four groups of inquiry components were found, which are different in the track that describes the relationship between development, experience, and challenge during the inquiry work in the ‘Research Physics’ program (see chapter 3.3.4). The research assumption regarding the relationship between development and experience and challenge was confirmed only for some of the inquiry components, as will be seen in the following, when groups 1-3 tend to be closer to the assumption, while group 4 is not commensurate with it.

1. **Inquiry components in which the development is significant and commensurate with a considerable degree of experience and challenge:** phrasing questions/goals, drawing conclusions, and building content knowledge.
2. **Inquiry components in which the development is significant and commensurate with a considerable degree of experience while the challenge is low:** performing an experiment, self-regulation and teamwork with the partner, written reporting on the inquiry, and choosing a topic.
3. **Inquiry components in which the development is low and is commensurate with a low degree of experience (even if there is great or low challenge):** locating information sources, using technological aids and a computerized laboratory, building a theoretical model, and teamwork with the rest of the peers.
4. **Inquiry components in which the development is low, despite a considerable degree of experience (even if there is great or low challenge):** planning an experiment, data processing, and oral reporting on the inquiry.

In the following we extend on each one of the groups. In each group there is a description of the relationship between development and experience and challenge of the students in the different inquiry components throughout all the stages of the program. According to the findings, the observations of the teams of students, and the conversations with the program designers, recommendations were formed for every inquiry component separately, which for the most part are commensurate with the students' reports on the ways of coping they encountered throughout the inquiry work (in chapter 3.1) and the factors that helped them develop in these inquiry components (in chapter 3.2).

Group 1. Significant development is commensurate with a considerable degree of experience and challenge: phrasing questions/goals, drawing conclusions, and building content knowledge, inquiry components in which the students' reports reflect a large degree of experience and challenge throughout all the stages of the program, as well as significant development in their ability to carry out these components. The research recommendation is to preserve the structure of the program existing in the inquiry components of this group.

Inquiry Component: Phrasing questions/goals

In this component, experience and challenge constituted a significant development for the students throughout the entire process of the inquiry work. The percentage of students indicating considerable difficulty in this component is among the highest relative to the other components, throughout the entire process of the inquiry work, although the difficulty steadily lessened in the last stages of the inquiry. During the program the students engaged in the first stage in the program asking the inquiry question and coped with the location and early identification of the factors that influence the phenomenon and conveying the thought into verbal phrasing in the form of a question/goal. In the more advanced stages, the students coped with repeated attempts to improve and focus the question throughout all the stages of the program (see chapter 3.1: Component of Phrasing the Questions). According to the students' report, they developed significantly in the performance of this component in the phrasing of the inquiry question, in the focus of the question according to the development of the inquiry, and in the ability to ask questions that will lead to an in-depth inquiry (see chapter 3.2: Component of Phrasing Questions).

Recommendations: In light of the above statements, and according to the students' reports, it is necessary to continue to provide considerable experience in the independent phrasing of the inquiry questions, through conversation with the teacher-mentor in order to focus the inquiry question. In particular, it is necessary to encourage consideration in the case of the choice of the question as a question that indeed can be investigated (links between measurable variables) and as a question that inspires interest in the researcher. In addition, it is necessary to continue to enable coping with dynamic inquiry and to give freedom to change the inquiry question accordingly and to focus it for the development of inquiry.

Inquiry Component: Drawing Conclusions

Here too experience and challenge are commensurate with the students' development in their ability to perform this component. In all the stages of the program the students experienced finding a relationship between the variables measured in the experiment in the given system, comparing the findings of the experiment to the theory, in order to reach deeper and more focused conclusions. During the experience in these practices, the students coped with difficulty in the implementation of high order thinking strategies, such as in-depth understanding of the principles and concepts relevant to inquiry, analysis, and synthesis. Primarily they had difficulty when gaps were found between the experiment findings and the theory and they needed to search for an explanation of this (see chapter 3.1: Component of Drawing Conclusions). The discovery of these gaps led them to another look at the findings of the experiment. Consequently, they reached the understanding that when the results of the experiment are not commensurate with the theory they are not necessarily mistaken results but it is possible that they are true and correct results. In addition, the students noted that from a comparison between the findings of the experiment and the theory and examination of the gaps they focused their conclusions, developed the critical thinking and ability to distinguish between what is important and what is not important in the drawing of the conclusions (see chapter 3.2: Description of the Aspects of Development in the Component of Drawing Conclusions).

Recommendations: In light of the above statements and according to the students' reports, it is necessary to continue to allow a long-term research process in order to reach an in-depth investigation and especially the broadening of the research when there are gaps between the experiment results and the theory. This is commensurate with the

students' reports that the coping in the search for an explanation of the gap between the theory and the experiment findings developed in them the component of drawing conclusions: "it was difficult for us to link between the project findings and theory – the results were not commensurate with the theory and we needed to try to find an explanation for this, this was hard, we thought together as a team, and from this difficulty we learned and developed in our ability to write good conclusions" (student 220, M). In addition, it is necessary to continue and to encourage joint work of the team members, with the teacher-mentor's support in the use of critical thinking in order to phase comprehensive and focused conclusions that address a wide variety of aspects in the researched phenomenon.

Inquiry Component: Building Content Knowledge

In this component, the percentage of students indicating considerable development, considerable experience, and considerable difficulty in the performance of this component is among the highest relative to the other components. During the program, the students built the content knowledge through practical experience in the laboratory. In other words, to deepen the investigation and understand the researched phenomenon, the students performed experiments and in parallel or later on learned the theory relevant to the researched topic. The students reported difficulty in the learning and understanding in-depth of the contents required for the project, especially when they do not have preliminary knowledge about the inquiry topics and the theoretical material is new for them. In addition, they coped with the complexity of the theoretical material and its high level. The difficulty increases especially when it is necessary to learn the topic independently, despite the teacher-mentors' support (see chapter 3.1: Component of the Building of Content Knowledge). From the coping with these challenges, the students deepened the understanding and knowledge on the researched phenomenon (for the most part contents beyond the high school curriculum), developed their ability to learn independently and their adjustment to new learning styles that generally are different from the school (like the integration of practical experience in the learning of the theory, collaborative learning). In addition, the students increased their learning responsibility and the awareness of the importance of this in order to build content knowledge and perform in-depth and significant inquiry (see chapter 3.2: Component of Building Content Knowledge.)

Recommendations: In light of the above statements and according to the students' reports, it is necessary to continue to allow students to learn diverse contents, also beyond the curriculum and according to the needs that arise from the experimental research. In addition, despite the difficulties, it is important to allow the students to learn and build content knowledge independently and to build it through practical experience in the laboratory (unlike the framework of their school, where for the most part the teacher is the center of the information and generally the teaching of the theory precedes the experiment). The students' coping with difficulties entailed by the learning in this way is valuable to their learning abilities. "It was hard for me the situation of independent learning during the inquiry work. Although there is the support of the teacher-mentor, it was hard for me to understand the theory related to the phenomenon, since I did not have previous knowledge at all and I needed to learn a lot alone and during the performance of the experiments. However, on the other hand this situation caused me to know how to learn by myself, what I did not do in the past." (student 217, F). The students noted that this component was based on character traits of natural curiosity, self-challenge, motivation and desire to succeed, investment, perseverance, seriousness, responsibility for learning, and openness to new topics and additional learning styles. In addition, the students brought up the contribution of the mutual fertilization in collaborative learning with the partner in the project. Alongside this, it is important to them the support of the teacher-mentors and academic counselors, in the giving of explanations for things that are not understood or are complicated for the students, in the identification of information sources relevant to the researched topic, in order to reach an in-depth understanding of the researched phenomenon.

Group 2. Significant development is commensurate with a considerable degree of experience, while the challenge is sparse: performing an experiment, self-regulation, and teamwork with the partner, written reporting on the inquiry, and choosing a topic. In these inquiry components the students' reports reflect considerable experience while the students were not greatly challenged and still experienced significant development in their ability to perform these components. The research recommendation is to preserve the existing structure of the program in the case that the experience was held in most of the inquiry stages and to increase it in the case it was held only in the final stage.

Inquiry Component: Performing an Experiment

In this component, the very fact of the considerable experience alone throughout all the stages of the inquiry was enough to allow the students significant development in this component, although they were not especially challenged in most of the inquiry stages. Only in the final stage did many students (above the mean frequency) report considerable difficulty in the performance of this stage. The percentage of students indicating considerable development in the intermediate and final stage in this component is higher than the other components and there is a significant increase in the percentage indicating from the preparation stage to the final stage. Indeed, in the early stages of the inquiry work the students carried out initial experiments to understand the researched phenomenon that constitute the basis for the final project. In the final stage, the students were challenged more than in the early stages since they engaged in more advanced and complex experiments and dealt with the dynamism of the performance of the experiment, such as change of the experiment system according to the directions of investigation, constant improvement of the experiment systems, and repeated attempts of the experiment in order to obtain more precise measurements (see chapter 3.1: Component of Performance of the Experiment). In the comparison to the school, many reported that the experiments carried out in the program were greater in number and were more complex and challenging, and some even reported that they did not carry out any experiments in the school. The students' coping with the difficulties that arise during the building of the experiment system and its performance led to development both in the shortening of the duration of time required for them and in the quality of the experiment system (the introduction of improvements in the building of the system in aspects of isolating variables, precision in measurements, and minimization of factors of error). In addition, in the advanced stages of the inquiry, the students carried out experiments independently, without prior briefing, but with the teacher-mentors' accompaniment and support (unlike in the school laboratory, in which for the most part the students receive a detailed briefing, which dictates the inquiry questions and ways of performance). Following this, the students displayed more independence and initiative in the performance of experiments than in the past, which also increased for the students their feeling of the ownership of the inquiry and their enjoyment of it. "Enjoy the experiment that we do. If it is not fun for you then make it yours, and be more independent in that you are the ones who create something new in the experiment system, which solves the problems, which

makes it better, and you will feel that it is yours” (student 226, M). In addition, the students reported that they developed their determination, perseverance, and creativity (thinking ‘outside of the box’) in providing an answer to problems in order to provide answer to problems that surface during the experiment (see chapter 3.2: Component of Performing an Experiment).

Recommendations: In light of the above statements and according to the students’ reports, it is necessary to continue to let students gain considerable experience in the component of performing an experiment and to cope dynamically and with the difficulties that arise during the building of the system and the performing of the experiment. It is necessary to do this gradually, as in the program: at first to give the student instruction from the teacher-mentor and the laboratory assistant in the building of the system and the implementation of parts of the system and to increase the students’ awareness of the importance of the isolation of the variables in the experiment, minimization of the factors of error, and precision in measurements. In the continuation, in the advanced stages of the inquiry and according to the students’ reports, it is necessary to continue to allow the students to carry out experiments independently (alongside the support of the teacher-mentor and laboratory assistant), and to encourage the student’s initiative, determination, and creative thinking, in order to overcome problems that arise during the carrying out of the experiment and eventually to provide a precise and focused response to the inquiry question. In addition, the students cited the resources that were placed at their disposal in the environment of the advanced laboratory: access to reliable and sophisticated measurement tools, to considerable and diverse equipment, and to teacher-mentors and laboratory assistants who facilitate the building of personally tailored systems for every research team.

Inquiry Component: Self-Regulation

The students’ development in their ability to perform this component was significant throughout most of the stages of the program and is commensurate greatly with experience and there is even a significant increase between the intermediate stage and the final stage in the degree of experience, while few students (under the mean frequency) reported considerable difficulty in the performance of this component. These students described a certain degree of difficulty (but not great) in the planning and organization of the inquiry work, difficulty in meeting the time schedule because of the performance of many other commitments (such as works and tests in the school), difficulty in making intelligent decisions especially in situations of uncertainty/powerlessness during the

inquiry work and coping with frustrations (see chapter 3.1: Component of Self-Regulation). In essence, the very demand for self-regulation in the inquiry work led the students to the development and improvement in the practices of the work management, such as improvement in meeting the time schedule following planning the work and an orderly time schedule, organizing the inquiry work and taking personal responsibility for the advancement of the inquiry and the quality of the inquiry. In addition, the students understood that situations of lack of certainty during the inquiry work are a part of the inquiry process and from them it is possible to grow and further the investigation. Consequently, they developed a firm position against situations of uncertainty using the ability to persevere, determination, and optimism. Moreover, the students reported that they developed creative and critical thinking in order to overcome these situations (see chapter 3.2: Component of Self-Regulation).

Recommendations: In light of the above statements, it is advisable to continue to raise the students' awareness of the importance of planning and organizing the inquiry work, planning a proper schedule (that includes the division of labor between the partners), and performing supervision of what is done during the inquiry work. In addition, it is advisable to let students deal with difficulties related to self-regulation (such as coping in situations of uncertainty, 'failures', reaching a 'dead end', and making decisions). However, it is necessary to do this to a certain degree (not high) as done in the program and alongside providing help and support (practical and mental) of the teacher-mentors and academic counselors. According to the students' reporting, it is important that the teacher-mentors will carry out follow-up after the progress of the inquiry work and the planning of the work, also to provide formative assessment of the inquiry work and to identify the students who are 'stuck' and to help them in earlier stages. In addition, the students note that because of their seriousness, personal taking of responsibility, self-motivation, adherence to the investigation, and use of creative and critical thinking, they succeeded in making decisions on the progress of the inquiry, and when they encountered situations of uncertainty or experienced frustrations. Since there is no explicit instruction in the program how to deal with these challenges, some of the students sought to carry out a lesson with the goal of teaching ways of coping with situations of uncertainty and with difficulties related to the management of the inquiry work and the meeting of time schedules.

Inquiry Component: Teamwork with the Partner

This component is also one of the components that many students (above the mean frequency) reported on great experience and development relative to the other inquiry components, although they did not experience especial challenge. The percentage of students indicating considerable difficulty performing this component is lower than other components. In the structure of the intervention of the program, one of the conditions in performing inquiry work in the program is the work in pairs (not individually) and continuous work of the regular pairs from the beginning of the inquiry process to its end (intermediate stage – in the eleventh grade, final stage – twelfth grade). In essence, this condition provides an opportunity for students to experience and develop their teamwork. Therefore, according to the students' reports, the very considerable experience in the teamwork during the inquiry work was enough to enable development in this practice. Few students described difficulties in the teamwork with the partner in the project, for instance, difficulty with coordination of times and division of the inquiry work and roles between them (see chapter 3.1: Component of Teamwork with the Partner). The development in this component was expressed in the sharing of the ideas of the students with one another, shared learning, and mutual fertilization both in the theoretical part and in the practical part of the inquiry work, performing division of work and division of roles between the staff members in order to increase the effectiveness of the work, and development of interpersonal skills, such as display of caring, consideration, giving space and respect to one another, providing support to the partner when needed, and creating good friendships (see chapter 3.2: Component of Teamwork with the Partner).

Recommendations: In light of the above statements, it is necessary to continue as done in the program, to perform the inquiry project with regular partners from its start to its end and thus to allow considerable experience in teamwork. According to the students' report, it is necessary to make certain of a fair and correct division of labor between the partners for the teamwork to be good. Students brought up the importance of the component of teamwork with the partner in an inquiry work as a factor that helped them develop not only in this component but also in additional inquiry components and (such as mutual fertilization in the building of content knowledge, brainstorming for ideas in the planning of the experiment, reinforcement and support during a crisis and frustration in situations of uncertainty).

Inquiry Component: Written Reporting on the Inquiry

According to the students' reports in the preparation stage and intermediate stage of the inquiry work, they did not experience considerably and were not challenged especially, and few students (under the mean frequency) reported considerable development in this component. Only in the final stage of the inquiry work was the development commensurate with the experience, and there is a significant increase in the percentage of students indicating considerable development from the preparation stage to the final stage. Indeed, in the preparation stage and the intermediate stage the inquiry activities were like a guided inquiry, in which the students received instructions for the organization of the data and their representation in writing. In contrast, in the final stage of the inquiry work the students experienced greatly in this component, were more careful about the documenting of the inquiry, wrote laboratory reports independently, and described the inquiry process. Towards the end of the inquiry work emphasis was placed on the writing of the summative work and the final presentation. We will note that despite the report of few students on the considerable difficulty in the performance of this component throughout all the inquiry stages the students describe a not insignificant number of difficulties (to a certain extent but not high), like the difficulty to persevere in the documenting of the inquiry in an ongoing and consistent manner during the entire inquiry (because of the lack of time and/or resourcefulness) and difficulty with the summarization of the main points in the writing of the work and the presentation (see chapter 3.1: Component of the Written Reporting on the Inquiry). It is reasonable to assume that the reporting on limited challenge is related to the fact that the support was enough to allow the students to significantly advance in these components. The development was expressed mainly in the final stage of the inquiry work in more organized, concise, understood, and clear writing. In addition, there was improvement of the ability of control, differentiation between what is important and what is less so, and making decisions in the writing of the work (see chapter 3.2: Component of the Written Reporting on the Inquiry).

Recommendations: In light of the above statements, the students should be given greater experience in this component also in the early stages of the inquiry and not only in the final stage of the inquiry work. According to the students' request, it is necessary to continue to bring up the students' awareness of the importance of the documenting of the inquiry in an ongoing manner from the start of the inquiry, and to encourage the writing of

an inquiry journal, which includes the entire inquiry process and its products, through which the students can perform control over their work and also will be helped by it towards the writing of the summative work. In addition, it is necessary to provide feedback to the students on their written work at sufficient frequency, so that the students can improve their writing and the quality of their work.

Inquiry Component: Choosing a Topic (that includes also the choice of directions of investigation during the inquiry work)

In this component, the development was commensurate with the experience only in the final stage of the inquiry work. The students' degree of experience in the final stage is average relative to the rest of the inquiry components and accordingly the degree of their development is close to the mean frequency (it is possible to see the trend of increase in the percentage of students indicating considerable development from the intermediate stage to the final stage). In addition, few students (under the mean frequency) reported considerable difficulty in the performance of this stage both in the intermediate stage and in the final stage of the inquiry work. Indeed, in the mirror of the observation and according to the students' reporting, in the final stage of the inquiry work the engagement in this component was more than in the previous stages. In the preparation stage activities were held in which the teacher-mentors chose the topic, in the intermediate stage the students chose the inquiry topic from a collection of topics, and in the final stage of the inquiry work the students performed renewed and independent thinking about the choice of directions of investigation, used judgment, and decided what to focus on in their inquiry. The students reported in the intermediate stage that it was hard for them to choose a topic, mainly because the topic is not known to them and is new for them, and in the final stage it was hard for them to focus on the chosen topic and to prevent dispersion to other directions of investigation (see chapter 3.1: Component of Choosing the Topic). They received support and direction from the teacher-mentors, and it is reasonable to assume that this support led to a reduction of the challenge for most of the students. In the final stage of the inquiry work, the students reported that they developed the ability to make decisions and the ability to focus on the chosen topic (see chapter 3.2: Component of Choosing a Topic). The students attribute the development in this component to the free choice given by the teacher-mentors of the inquiry topic and the investigation directions.

Recommendations: In light of the above statements, it is necessary to let the students use their judgment independently in the choosing of the investigation topic and to allow them to cope with the dynamism of the choice of ways of investigation throughout all the stages of the inquiry work and not only in the final stage. However, it is necessary to have the teacher-mentors give direction and support, such as giving suggestions to the students for directions of investigation and ways of performing investigation that give an answer to the inquiry question and help advance in the inquiry, but as long as the students' independence is not harmed.

Group 3. Low development is commensurate with a slight degree of experience (even if there is great or little challenge): locating information sources, using technological aids and a computerized laboratory, building a theoretical model, and teamwork with the rest of the peers. In these inquiry components the students' reports reflect little experience and accordingly little development in their ability to perform these components (even if the students' reports reflect great or little challenge in the performance of these components). The research recommendation is to change and improve the existing structure of the program, including more experiences in these components.

Inquiry Component: Use of technological aids and a computerized laboratory

In this component, few students (under the mean frequency) reported considerable experience, considerable difficulty, and considerable development in the use of technological aids and a computerized laboratory (when only in the final stage the percentage of the students is almost equal to the mean frequency). The students who reported considerable experience reported that they had a certain difficulty (but not great) in the operation of different sensors because of lack of knowledge/experience in this, and some of them dealt with lack of precision and sensitivity of the technological measurement instruments (see chapter 3.1: Component of Using Technological Aids and a Computerized Laboratory). The students who reported significant development discovered the importance and advantages in the use of technological aids and a computerized laboratory that they did not know beforehand and became professionals in them. Through them it is possible to broaden and deepen the researched phenomenon, and sometimes the use of these instruments makes the way of the investigation significantly easier (see chapter 3.2: Component of Using Technological Aids and a Computerized Laboratory).

Recommendations: In light of the above statements, and according to the students' reports, it is necessary to continue to give the students access to advanced equipment, technological tools, and a computerized laboratory and to allow them to conduct trial and error in them. Alongside this, it is necessary to provide instruction of the teacher-mentor and laboratory assistant, explanations and illustration of the action and the use of these instruments. According to the students' request, there is need for the maintenance of the laboratory equipment and the purchase of more sophisticated equipment, which will be less sensitive to noises, to make it easier for the students to collect the measurements. However, in order to make a significant change in the students' development in this component, it is necessary to make certain that the experience in technological tools and a computerized laboratory will be greater among most of the students in all the stages of the program.

Inquiry Component: Building a Theoretical Model (that includes building a theoretical model in a computerized manner)

In this component too, the students did not experience greatly, were not especially challenged, and only a few students (under the mean frequency) reported considerable development in the performance of this component. We note that although there is a trend of increase in the final stage of the inquiry the percentage of students indicating considerable experience in this component is lowest in the two stages, both in the intermediate stage and in the final stage of the inquiry work. As commensurate with the structure of the intervention, the program was built so that the students focused from the beginning on the empirical inquiry that required less preliminary knowledge. Only in an advanced stage of the inquiry will the students be asked to build a theoretical model for the complex phenomenon. In the end, in the mirror of the observation, emphasis was not placed on the building of a theoretical model, except for in the subgroup that engaged in the building of a theoretical model using computational modeling (in which they did not have experience in the past). These students coped with the need for the mastery of the theoretical background relevant to the inquiry, of the high mathematical knowledge required accordingly, and of the new programming language Python (see chapter 3.1: Component of Building a Theoretical Model). Consequently, the students reached a deeper understanding of the physical concepts and principles related to the researched

phenomenon and the understanding of the process of the building of a theoretical model. In addition, the students developed expertise in the writing in a computer programming language (see chapter 3.2: Component of Building a Theoretical Model).

Recommendations: In light of the above statements and according to the students' reports, it is necessary to further increase the students' awareness of the importance and effectiveness of the building of a theoretical model, which enables reaching a deeper inquiry and a deeper understanding of the researched phenomenon and even enables the prediction of additional phenomena. One of the ways of doing this is through greater experience in computational modeling that enables building a theoretical model during the inquiry process and not to be satisfied with a course that is taken before the beginning of the project (which gave the basic tools for computational modeling). For this purpose, it is necessary to expose the students to observe existing computational modeling and to provide more close help from the instruction staff while using computational modeling during the inquiry itself.

Inquiry Component: Teamwork with Peers in the Broader Group

In this component, the students did not have great experience and there is even a significant decline in the percentage of the students who indicate considerable experience from the intermediate stage to the final stage of the inquiry process and few students (under the mean frequency) described difficulties in this component because of the lack of engagement in it. In addition, few students (under the mean frequency) reported that they developed to a considerable extent in this component. In the mirror of the observation, in the stage of the intermediate report there was a framework of presentation to peers and peer assessment, but as a rule peer assessments were not held in an ongoing and regular manner. In addition, in the program emphasis and importance were not placed on the creation of interactions among the rest of the peers in the broader group. The students express lack of satisfaction with the structure of the intervention of the program on this issue (see chapter 3.1: Component of Teamwork with the Peers in the Broader Group). The few who reported considerable development noted the importance of teamwork with peers in the broader group and particularly the performance of peer assessment, which provides them with proposal for the improvement of the work and proposals for the continuation of the investigation, gives them satisfaction and confidence for their work and their presentation, and exposes them to other researches of their peers (see chapter 3.2: Component of Teamwork with Peers in the Broader Group).

Recommendations: In light of the above statements, and according to the students' request, it is advisable to have in the program more activities that include peer assessment, which is another source for students to receive constructive criticism and direction to improve the inquiry work and encourages them to perform follow-up and control of their work. It is advisable also to undertake cohesion building activities to create more opportunities for social interactions that cause the creation of social relationships and the development of interpersonal skills.

Inquiry Component: Locating information sources

A few students (under the mean frequency) reported that they had experience in this component to a great degree, but this is the component in which the least number of students indicated considerable development relative to the other inquiry components. However, there is a considerable trend of increase from the intermediate stage to the final stage in the number of students who report considerable difficulty in the performance of this component. According to the students' reports, indeed in the first stages (in the preparation stage and in the intermediate stage) the students less were required to identify sources relevant to the researched topic and therefore the students less had experience in this component. Only at a later stage of the inquiry work, primarily in the final stage did they encounter considerable difficulty in identifying sources relevant to the researched phenomenon, for different reasons: the uniqueness of the phenomenon (a phenomenon that is not common), and a low number of sources engaging in the phenomenon were found, and/or the lack of knowledge and experience in finding esteemed and high level information sources (see chapter 3.1: Component of Locating Information Sources). In the mirror of the observation, the students did not receive an answer to these difficulties (on the part of the teacher-mentors) and the students less engaged in this component and were satisfied with what they achieved or with the few sources that the teacher-mentor gave them. Accordingly, there was no significant development in this component among most of the students. A few reported that they improved the technique of searching for information sources on the Internet (see chapter 3.2: Component Locating Information Sources).

Recommendation: In light of the above statements, and according to the request of the students, it is necessary to add activities aimed at experience in the component of locating information sources already in the preparation stage (in the first year of the program) and during the work on the inquiry project. In addition, it is necessary to draw the teacher-mentor's attention to provide more help in the search for information sources throughout all the stages of the inquiry especially when the researched phenomenon is not common and it is difficult to find sources relevant to the phenomenon.

Group 4. Low development, despite a considerable degree of experience (also if there is great or little challenge): planning an experiment, processing data, and oral reporting on the research. In these inquiry components the students' reports reflect considerable experience throughout most of the stages of the program, but conversely little development in their ability to perform these components (even if the students' reports reflect great or little challenge in the performance of these components). The recommendation of the research is to change and to improve the existing program structure and emphases of the instruction in order to provide tools for the students through which more students can develop in these components, and not only to rely on the degree of considerable experience that is given in the program

Inquiry Component: Planning an Experiment

Few students (under the mean frequency) reported considerable development in the performance of this component, although many students (above the mean frequency) reported considerable experience throughout most of the inquiry work. There is even a significant increase in the percentage of students who indicated considerable experience between the preparation stage and the final stage of the inquiry work, but still few students experienced significant development also in the final stage. In addition, the students were not especially challenged in the first stages of the inquiry (the preparation stage and the intermediate stage), but towards the final stage of the inquiry work many students (above the mean frequency) reported considerable difficulty in the performance of this component.

Indeed, in the mirror of the observation and according to the students' reports, in the advanced stages of the inquiry work and mainly in the final stage of the inquiry work, the students had more experience in this component, and more planned experiments

independently. Mainly in the final stage the students reported that they had difficulty in planning the isolation of variables of the experiment, coped with the dynamism of the experiment planning according to problems that arise during the experiment, and were required to perform improved planning of the experiment system (see chapter 3.1: Component of Planning an Experiment). The few who reported considerable development in the final stage of the inquiry work reported that they improved in the more detailed planning of the experiment, including identification and isolation of the variables, and developed their creativity and initiative, in order to improve the planning of the experiment and to find solutions to the problems that appeared during the work (see chapter 3.2: Component of Planning an Experiment). It is possible to explain the limited feeling of development among the students with emphases of guidance the students obtained in this component. The observation indicates that the component of planning an experiment is required in the program but was not tackled explicitly. The program did not engage explicitly with tools for planning, for example structured strategies for problem solving. The feedback on the planning existed according to the opinion of each and every teacher-mentor, without shared patterns, when some of the teacher-mentors even propose planning solutions for the students. It is reasonable to assume that the students did not recognize this component as a meaningful component, and some did not cope with it independently.

Recommendations: In light of the above statements, it is necessary to increase the degree of challenge in the performance of the planning of the experiment already in an earlier stage in the inquiry work. It is necessary to enable students in the program to perform the component of planning an experiment independently as early as possible alongside the teacher-mentor's support and to ask the students to write a detailed plan for the experiment that includes the isolation of variables in the best way and to improve it as much as possible with the progress of the inquiry. The few students who reported considerable development explained that their very coping independently with the different difficulties that arose during the planning of the experiment led them to development. It is necessary to add in the emphases of instruction the attention of the teacher-mentors to examine the students' initial planning and to provide them with feedback that will also include suggestions for improvement and thus give the students the tools to develop in this

component. In addition, some of the students noted the contribution of group thinking to the development in this component – brainstorming with the project partner led to finding creative ways to plan a better experiment system.

Inquiry Component: Processing data

In the stage of preparation alone, many students (above the mean frequency) reported considerable practice and considerable development in this component and in this stage few students (below the mean frequency) experienced considerable difficulty in the performance of this component. However, later on, in most of the process of the inquiry work, in the intermediate stage and in the final stage, few students (under the mean frequency) reported considerable development in this component, despite the considerable experience in these stages, and also in these stages there was no significant challenge. However, there is even a significant decline in the number of students who indicated development in this component from the preparation stage to the intermediate stage of the inquiry work.

Indeed, corresponding with the structure of the intervention of the program and in the mirror of the observation, in the preparation stage the students were exposed to different instruments and computer programs (like Excel) that enable the professional processing of the data (including graphical presentation). Some of them did not know in the past a computerized environment for data processing and/or did not build graphs from raw data and were exposed to this only in the program. Accordingly, in this stage regarding their experience in the past the students reported that the very experience with these new tools led them to significant development in this component. In the later stages of the inquiry, in the intermediate stage and in the final stage of the inquiry work, a few reported considerable difficulties in performing data processing independently and difficulty with classification of the data and processing the data because of the large scope of the data (see chapter 3.1: Component of Processing Data). Most of the students processed the data professionally and specialized in this, both in the quality of the performance and in the speed of the performance of this component. However, nevertheless only a few students reported considerable development in these stages. It is reasonable to assume that the students think that they have realized the development in this component in the early stages of the inquiry and that they already are experts in the

performance of data processing in the Excel program and therefore there is a lack of indication of considerable development in the later stages of the inquiry. Only a few noted further development in these stages, like evaluation of the range of uncertainty of the measurement and comparison to the range of error of the experiment and development of critical thinking following the engagement in the data processing (see chapter 3.2: Component of Processing the Data). In retrospect, it could have been that the program set low standards for performance in this component and hence the low development in the later stages of the inquiry work. The observation indicates that the data processing of the students was similar largely to that of students who use the school physics laboratory (evaluation of the relative error and comparison to the theoretical value and description of the factors of error without reference to the evaluation of the uncertainty of the experiment). The students did not make enough use of the tool of more advanced statistical analysis, so that this component indeed did not challenge the students beyond the standards to which they were first exposed in the beginning of the program, in parallel to their entrance into the program in the school.

Recommendations: In light of the above statements, as done in the program, already in the preparation stage it is necessary to expose and teach the students the use of different tools and computer software programs (like Excel) for the processing of the data in a professional manner and to have them gain experience in them. However, this is not enough. In the advanced stages of the inquiry, it is necessary to set for the students high standards in the component of data processing, to ask them to address also the statistical analysis of the dispersion of the findings, evaluation of the range of uncertainty in the measurements, and comparison between the experiment and the theory in the bounds of the error. These standards will set for the students a higher threshold, will constitute a challenge, and will develop the students' critical thinking, and it is possible that they will lead to further development of the students in this component.

Inquiry Component: Oral Reporting on the Inquiry

In this component, in most of the inquiry stages, both in the intermediate stage and in the final stage of the inquiry work, many students (above the mean frequency) reported considerable experience in this component (in the preparation stage there was barely any experience in this component). Although there was a significant increase in the number of

students who indicated considerable experience from the preparation stage to the final stage of the inquiry work, and there is even a significant increase in the number of students who experienced considerable development in this component in these stages, still only a few students (under the mean frequency) reported considerable development in this component throughout all the inquiry stages (in the final stage it is close to the mean frequency). In addition, although there is a trend of decline from the preparation stage to the final stage of the inquiry work in the number of students who experienced great difficulty in the oral reporting on the inquiry before an audience, this component still constitutes a challenge for many students (above the mean frequency) throughout all the inquiry stages, also in the final stage of the inquiry work.

Indeed, according to the students' reports, the students report considerable difficulty in all the stages – to convey the thinking into oral expression and to master the knowledge accumulated in the inquiry during the presentation, and mainly difficulty overcoming the anxiety, the stress, and the embarrassment that exist when standing in front of an audience (see chapter 3.1: Component of the Oral Reporting on the Inquiry). In addition, according to the students' reports and in the mirror of the observation, the experience in this component was mainly in the advanced stages of the inquiry, towards the submission of the intermediate report (towards the end of the eleventh grade) and towards the submission of the summative report (towards the end of the twelfth grade), where they had to reflect a long-term inquiry process and deal with the regular criticism of the peers and the teacher-mentors. The students reported that these experiences led to an improvement of the presentation ability and their standing in front of an audience, an increase in their sense of efficacy, and a reduction of the stress and anxiety in presenting orally. In addition, the feedback given to them after the presentation enabled them to perform criticism of their work (see chapter 3.2: Component of Oral Reporting on the Inquiry). However, as mentioned, the percentage of students who reported considerable development is not sufficiently high relative to the rest of the components although there is a significant increase from the stage of preparation to the final stage of the inquiry work. In the mirror of the observation, despite the reporting of the students on the considerable experience in this component, in actuality many opportunities were not provided for the students to have experience in this component, even in the advanced

stages of the inquiry, aside from significant experiences towards the submission of the intermediate report (towards the end of the eleventh grade) and towards the submission of the summative report (towards the end of the twelfth grade). It is reasonable to assume that the students reported considerable experience that the questionnaires were held near their presentation and the preparation for the presentation gave them a feeling of great experience in this component. Another possibility is that it is possible that the students are comparing their degree of experience relative to other frameworks, such as the school, where the experience in oral presentation is little or nonexistent. In addition, in the mirror of the observation, the support by the teacher-mentors towards the oral presentation was according to the opinion of each and every teacher-mentor. The program did not engage explicitly with the instruments for the oral presentation and with the methods for coping with emotional difficulties caused by standing in front of an audience. In addition, an opportunity was not granted to the students to improve their presentation after they received the feedback.

Recommendations: In light of the above sentences, it is necessary to provide further opportunities for students to experience in the oral reporting of the inquiry also in the preparation stage and not only in the advanced stages of the inquiry. According to the students' request, it is necessary to perform intermediate presentations, in the middle of the year and not only at the end of the year. This is so the students will acquire experience in presenting to an audience, will draw conclusions from previous presentations, and will can improve their presentation. Students note that the performance of rehearsals of the presentation before family and friends, planning ahead of time of the manner of presentation, and mastery of the content knowledge and the inquiry process before the presentation raise the self-confidence and self-efficacy to present before an audience. In addition, it is necessary to add in the instruction emphases to perform adequate preparation towards the final presentation that will provide tools for the oral presentation, and to perform simulations of the presentation not only before the family and friends but also before their teacher-mentors so as to obtain feedback of an expert. To reduce the degree of challenge, it is advisable to provide greater reference and support for challenges that are before the students in the component of the oral reporting of the inquiry, including emotional challenges. Moreover, it is advisable to provide time and a framework for the implementation of the feedback given after the presentation in order to improve their performance in the presentation.

4. Findings and conclusions for the Second Research Question

– The Students' Perception of the "Research Physics" Learning Environment, (Particularly, the Teacher's Roles, the Student's Roles, and the Learning Resources)

This chapter describes the findings and conclusions that answer the second research question:

- 2) How did the student perceive the **learning environment** in the 'Research Physics' program along their engagement in the various stages²⁸ of the inquiry work?²⁹ In particular: **roles of students and teachers** and **learning resources**

This chapter describes the qualitative and quantitative analyses of the **students' perception of the "Research Physics" learning environment** (which is held at the Davidson Institute, the Weizmann Institute, Israel), an environment that focuses on the performance of inquiry projects. The research study focused particularly on the **students' perception of the roles of the teacher and the student during the performance of the inquiry work and their perception of the learning resources provided to them in this environment**. For the purpose of the collection of the information about this, three directions of investigation were examined: first, the perception of the students of the differences between activities in the laboratory in the school framework and in the Research Physics framework; second, questions regarding the students' attitudes towards the inquiry process and the Research Physics learning environment and their attitudes towards their ability to perform inquiry work and the contribution of the program to their performances, and third, examination of the students' degree of satisfaction of with the instruction of the teacher-mentor in the Research Physics program and the reasons for it. Accordingly, the chapter is divided into three parts.

²⁸ Stages of the inquiry work: a preparation stage for the inquiry project, an intermediate stage, and a final stage of inquiry work.

²⁹ Quantitative & Qualitative instruments: Attitudes questionnaire, Summative questionnaire, Interviews

The findings in this chapter were taken from interviews with students (11 students out of 34) conducted at the end of the eleventh grade. Students' answers to the questionnaires held in the intermediate stage of the project (eleventh grade, N=33) and in the final stage of the project (twelfth grade, N=34) (No data in the preparation stage – tenth grade. The reason is that in the preparation stage the students have not yet started their inquiry project but have undertaken short term inquiry activities in order to acquire different inquiry skills and prepare for the performance of the inquiry project and the inquiry work on the great project they began in the eleventh grade and finished at the end of the twelfth grade).

4.1 The Students' Perception of the Differences between Activities in the Laboratory in the School Framework and the Research Physics Framework (a Learning Environment Focusing on Inquiry Projects)

This chapter describes the students' perception of the differences between activities in the laboratory in the school framework and the Research Physics framework from the responses of the students in the Attitudes Questionnaire (see Appendix 1.3). From this comparison it is possible to characterize the students' perception of the "Research Physics" learning environment. The questionnaire was held at two times, during the intermediate stage (in the eleventh grade, February 2018, N=33) and about a year later during the final stage of the project work (in the twelfth grade, January 2019, N=34). In the questionnaire the students were asked to answer the questions, "In your opinion, to what extent is there a difference between activities in a laboratory in the school and activities you performed in the framework of the Research Physics Program? (Choose from three options: large difference / small difference / no difference.) Note at least two main differences in your answer."

4.1.1 Quantitative Analysis – Degree of Difference between Activities in the Laboratory in the School Framework and the Research Physics Framework according to the Students (in Stage 2 and Stage 3 of the Inquiry Work)

The following figure represents the **students' perception of the degree of the difference between activities in the laboratory in the school framework and those in the Research Physics framework** –the intermediate stage (in the middle of the school year, eleventh grade) and the final stage of the inquiry work (in the middle of the school year, twelfth grade).

The question was: “In your opinion, to what extent is there a difference between activities in the laboratory in the school and activities you performed in the framework of the Research Physics Program? (Choose from three options: great difference / small difference / no difference.)

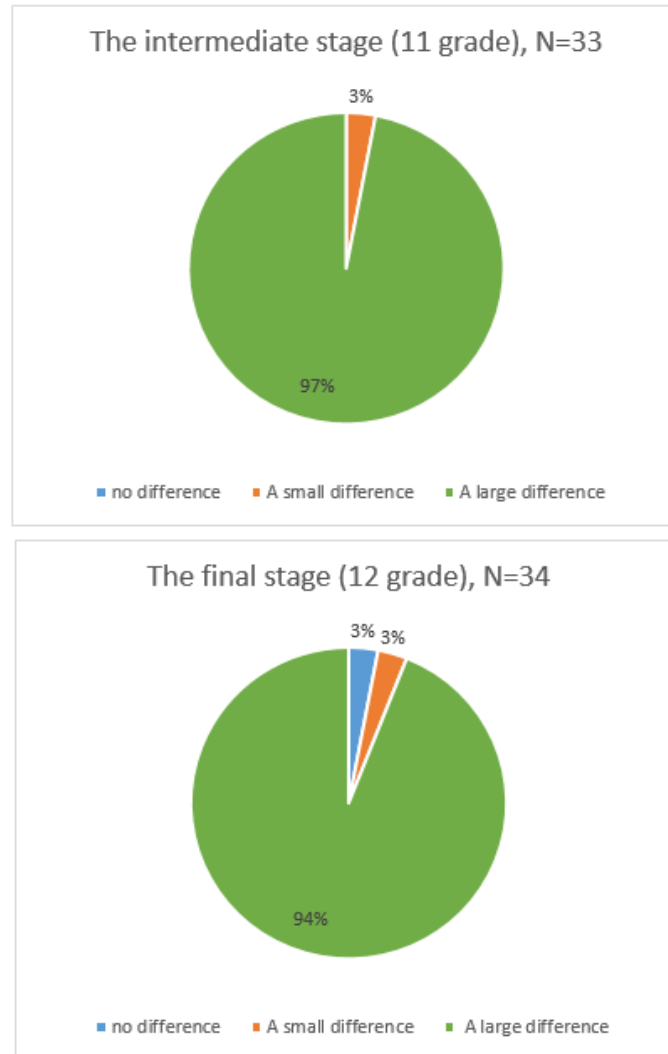


Figure 59: Report of Students of the Degree of the Difference between Activities in the Laboratory in the School Framework and in the Research Physics Framework – In the Intermediate Stage (N=33) and in the Final Stage of the Inquiry Work (N=34) (Sigron, M)

It is possible to see from the above figure (pie charts) that most of the students indicate that there is a great difference between activities in the laboratory in the school framework and the Research Physics framework both in the intermediate stage (97%) and in the final stage (94%) of the inquiry work, when the difference between the stages is not meaningful.

4.1.2 Qualitative Analysis – Description of Main Differences between the Research Physics Framework and Laboratory Activity in the School Framework (in Stage 2 and Stage 3 of the Inquiry Work)

This subchapter presents a qualitative analysis of the students' descriptions of the main differences between the Research Physics framework and the laboratory activity in the school framework, from the Attitudes Questionnaire (see Appendix 1.3), at the two times, during the intermediate stage of the inquiry work (in the middle of the eleventh grade school year, 2.2018, N=33) and about a year later during the final stage of the inquiry project (through the end of the twelfth grade school year, 1.2019, N=34). Appendices 4.1.1 and 4.1.2 present the description and illustrations of the students' quotes in the two stages, in the intermediate stage (eleventh grade) and in the final stage (twelfth grade) of the inquiry work.

4.1.2.1 Stage 2 – Intermediate Stage of the Inquiry Work (11th Grade) – Description of Main Differences between the Research Physics Framework and the Laboratory Activity in the School Framework from the Student's Viewpoint

The following section presents a qualitative analysis of the students' descriptions of the main differences between the Research Physics framework and the laboratory activity in the school framework, during the intermediate stage of the inquiry work (in the middle of the eleventh grade school year, 2.2018, N=33). In the Attitudes Questionnaire (see Appendix 1.3), the students were asked to describe two main differences between the activities in the laboratory in the school framework and the Research Physics framework. From their answers, it is possible to see the students' perception of the learning environment that focuses on the inquiry projects, and in particular, their perception of the role of the students and the teachers in the inquiry work, the learning resources, and the support given to them, in the following aspects (Appendix 4.1.1 presents examples of student citations that illustrate these aspects):

1. In the Research Physics framework, the choice of the researched topic was undertaken by the student and not by the teacher, as generally done in the school. The students report that in the Research Physics framework, the students are given the possibility of choosing the researched topic.

2. In the Research Physics framework, the students carry out laboratory activity more independently throughout the entire inquiry process, from asking the question to choosing the way of the investigation (planning and performing an experiment) to collecting and analyzing the findings, with the accompaniment and direction of the teacher-mentors. In contrast, in the school it is customary to give a full laboratory briefing from the teacher, from the giving of the experiment aim and performance instructions to the writing of the experiment conclusions.
3. In the Research Physics framework, the practical experience in most of the cases precedes the learning of the theory or is in parallel to it, in the school framework for the most part the laboratory activity after the learning of the theory. In other words, in research physics the building of the knowledge of the students is based on the experiments they perform and in parallel on the learning of theoretical content (for the most part, the experiments precede the theory). The students tell that in this way they achieve a deeper understanding of the physical phenomenon.
4. In the research physics framework, there is active learning, in which the students are more involved and active in the lessons and in the building of the content knowledge than in the school.
5. In the research physics framework, the students reach the in-depth understanding of the physical phenomenon and broaden the horizons (contents beyond the curriculum), as opposed to in the school there is no time to go in-depth beyond the curriculum and beyond the material required for the high school matriculation certificates.
6. In the research physics framework, there is more independent learning than in the school, where the student learns theoretical material that is new for him.
7. In the Research Physics framework, self-management of the investigation and independent organization of the schedule and the work journal are possible, as opposed to in the school framework, in which the teacher manages the lesson and the pace of the learning.
8. The research physics framework offers many more opportunities for teamwork among the students (work in pairs) than in the school, thus leading to cooperative learning with the partner and mutual fertilization, brainstorming, acceptance of

- support from the partner, and development of interpersonal skills, such as giving help, consideration of the pace of learning of the project partner, and listening and accepting the opinions of the other person.
9. Receiving support and a personal attitude between the teacher-mentor and the student (every research team has a close teacher-mentor for the duration of the entire inquiry work) more than with a teacher in the regular class.
 10. In the Research Physics framework, they are exposed to the world of the scientist/researcher more than in the school framework, mainly since they understand the nature of the inquiry process and there is also considerable practical experience.
 11. In the research physics framework, the results of the experiment are not known ahead of time and are not necessarily commensurate with the expected theory and it is necessary to provide explanations of the gap between the experiment findings and the theory. In contrast, in the school framework the results are known beforehand to the teacher/student, and mainly the goal of the experiment is to confirm the theory learned in the classroom.
 12. There is a higher level of experimentation in the research physics framework than in the school, for different reasons. The first reason is a long-term experiment, which raises the level of the experiment – in research physics it is necessary to carry out repeated experiments and to constantly improve the experimentation system, in order to reach as accurate results as possible, to differentiate from the school, where generally it is customary to perform a one-time experiment during the year. A second reason is the complexity of the theoretical content relevant to the experiment – the content of the researched topic in research physics is beyond the curriculum and its level is high relative to the school. A third reason is the complexity of the equipment – more use of technological instruments and a computerized laboratory that increase the level of the inquiry. The fourth reason is the performance of an experiment independently increases the difficulty and complexity of the experiment.

4.1.2.2 Stage 3 – Final Stage of the Inquiry Work (12th Grade) – Description of Main Differences between the Research Physics Framework and the Laboratory Activity in the School Framework from the Student’s Viewpoint

The following section presents a qualitative analysis of the students' descriptions of the main differences between the Research Physics framework and the laboratory activity in the school framework, during the final stage of the inquiry project (through the end of the twelfth grade school year, 1.2019, N=34). In the replay attitudes questionnaire (see Appendix 1.3), the students were asked again to describe two main differences. From their answers, it is possible to see the students' perception of the learning environment that focuses on the inquiry projects, in the following aspects (Appendix 4.1.2 presents examples of student citations that illustrate these aspects):

1. In research physics, the student is allowed to propose and to choose the directions of investigation, when, to differentiate, in the school the teacher (the education system) decides upon the objectives.
2. The research physics framework enables a change in the objectives of the investigation and reaching unexpected places because of the dynamism of the inquiry process and field of interest, while in the school the objectives are pre-defined and unchangeable.
3. Research physics enables freedom of action and independence throughout the entire inquiry work and leading of the inquiry project. In contrast, in the school generally the teacher is the one to lead the laboratory activity and the student works according to the teacher's instructions and there is no real room for the student's independent thinking and doing.
4. In research physics, the building of the knowledge is based first on practical experience and relying on this the students learn the theory. To differentiate, in the school, generally, the building of the knowledge is based first on the theory and relying on it they perform experiments. In general, there is more practical experience in the research physics program than in the school, and in the school greater emphasis is placed on the learning of the theory.
5. In research physics the student's degree of responsibility for learning and advancement of the inquiry project is greater than in the school.

6. In research physics the student is more involved and active in learning and in investigation than in the school, where the student builds the knowledge and the understanding.
7. In research physics the contents are broader than in the school and more complex.
8. In research physics there is greater depth in the topic than in the school.
9. Research physics enables more independent learning than in the school.
10. In research physics the handling of formulas is different than in the school. In the program we attempt to understand the aim of the formula, how it is created, prove or compose the formula, the relevance to the inquiry, as opposed to the school, where the formulas are given and generally do not show the proof.
11. The research physics framework enables the student to manage the work and to organize the time schedule, while in the school the teacher is the one to manage the lesson and what happens in it.
12. In the research physics framework, the students face more complex challenges than in the school of making decisions, learning from mistakes and failures, coping with situations of powerlessness and uncertainty (as expected in the inquiry process).
13. In the research physics framework, they are exposed to cooperative learning with the partner and to teamwork for the long term and discover its importance (such as mutual fertilization, joint decisions, division of labor and responsibility, and support of the partner), to differentiate when in the school the work is generally personal.
14. In the research physics framework, a more personal relationship is created between the student and the teacher-mentor than between the student and the teacher of the school, which is expressed also in personal follow up after the team of students and the teacher-mentor is more available than the teacher in the school.
15. In research physics the teacher-mentors are partners in the investigation since for the most part they do not know the answer as opposed to the teacher in the school, who for the most part knows the answers ahead of time.
16. In research physics there is room for the experiment results that are not expected (which are not commensurate with the theory) and constitute investigation, to differentiate the results of experiments performed in the school are known ahead of time and generally their goal is to confirm the theory.

17. In research physics there are more means to perform inquiry than in the school: an abundance of equipment, modern and sophisticated equipment, time for performing the inquiry, and expertise of the teachers to guide the inquiry.

4.1.3 Main Findings- Student's Viewpoint of Main Differences between the Research Physics Framework and the Laboratory Activity in the School Framework

The following table presents a summary of the students' description of the main differences between the research physics framework and laboratory activity in the school framework, which arose in the intermediate state (stage 2, N=33) and the final stage (stage 3, N=34) of the inquiry work. From this comparison it is possible to characterize the students' perception of the "Research Physics" learning environment. The differences were divided into four categories: management of the inquiry work, building content knowledge, teamwork, and in general the similarity to the world of the scientific researcher.

Table 15: Main Differences between Research Physics Framework and Laboratory Activity in the School Framework from the Student's Perspective (Sigron, M)

Aspect	Topic of the Difference	Research Physics Framework	Laboratory Activity in the School Framework	Stage
Management of the work in the laboratory activity	Degree of independence of the student and degree of involvement of the teacher-mentor / teacher in the laboratory activity	The students choose the inquiry topic and suggest ways of investigation in the continuation of the work	The teacher chooses the topic researched in the laboratory and decides upon the direction of investigation of the laboratory activity	2, 3
		Enabling a change in the investigation objectives and reaching unexpected places because of the dynamism of the inquiry process	The objectives are defined ahead of time (the curriculum of the Ministry of Education) and cannot be changed	3
		Giving the student freedom of action and independence throughout the entire inquiry work. The student carries out laboratory activity independently– from asking the question and choosing the way of investigation (planning and performing the	In most of the laboratory activities the teacher gives a full laboratory briefing – from giving the goal of the experiment and performance instructions until writing conclusions of the experiment. The teacher leads the	2, 3

		experiment) to collecting the findings and analyzing them. Giving the possibility to the student to lead the inquiry project alongside direction by the teacher-mentors.	laboratory activity and the student works according to his instructions and there is no real room for the student's independent thinking and doing.	
	Degree of responsibility of the student for learning and advancement of the project	The student's responsibility for the learning and the advancement of the inquiry project is very great although the teacher-mentors provide accompaniment and support	Degree of responsibility of the student for existing learning but less than the research physics framework, since in the school the teacher teaches the material and is responsible for the pace of learning	3
	Planning and organizing the inquiry work and schedule	The student's self-management – organization of the schedule and work journal of the inquiry independently	The teacher manages the lesson and the schedule of the laboratory activity	2, 3
	Coping with the dynamism of the inquiry and with situations of uncertainty during the work in the laboratory	Students cope with complex challenges during the inquiry work, such as making decisions, learning from mistakes and failures, coping with situations of powerlessness and uncertainty (as expected from the inquiry process). In addition, the teacher-mentors provide the student with time to deal with these challenges and do not bring the student the answer to the challenge, in parallel they encourage and provide direction.	The students less encounter difficulties in the performance of the laboratory activity since the experiments are very clear, less than the form of trial and error and there is no reaching a situation of a dead end or uncertainty. In addition, if the student encounters difficulty, the teacher generally solves the difficulty and gives the answer.	3
Building content knowledge	Practical experience in the laboratory (experiments) precede the theory or the opposite	The structuring of the knowledge is based first on the practical experience and on this basis the students learn the theory. In other words, the practical experience in most cases precedes the learning of the theory or is parallel to it.	Generally, the building of the knowledge is based first on the theory and on this basis experiments are performed. That is, for the most part the laboratory activity is after learning of the theory.	2, 3
	Active learning (in which the student builds the knowledge in the lesson)	There is more active learning than in the school, the student is involved during the lesson and he builds his knowledge and understanding during the inquiry. This is following the giving of a space of action and independence to the student by the teachers	The teacher builds the knowledge for the student during the lesson and the student is less active and involved in the building of the knowledge.	2, 3

	Level and depth of the theoretical content	Enabling learning of contents beyond the curriculum and broadening of the horizons.	The teachers adhere to the curriculum of the Ministry of Education	2, 3
		The students reach an in-depth understanding of the researched physical phenomenon	There is no time to go in-depth in the topic and to learn beyond the level required in the high school matriculation examination	2, 3
		Handling formulas – there is the attempt to understand the goal of the formula, how it is created, prove or compose the formulas	Generally the formulas are given to the students and the proof of the formula is not shown	3
	The student's independent learning of the theoretical content	Considerable independent learning of the theoretical content relevant to the inquiry is required, and the student in most of the inquiry process searches for knowledge sources and builds his knowledge (receiving direction from the teacher)	Less independent learning is required and generally the teacher is the one who reveals the knowledge and builds it for the student during the lesson	2, 3
Teamwork	Teamwork of the student with the project partner	Many more opportunities are given for teamwork between the students than in the school, and the teamwork is for the long term (work in pairs in all the meetings for two consecutive years). Following the experience in the program, the students discover the importance and essentialness of teamwork and of cooperative learning: mutual fertilization, division of the work, reciprocal commitment, joint decisions, receiving support from the partner, and development of interpersonal skills in teamwork (such as giving help, consideration of the project partner's pace of learning, listening and accepting opinions of others)	Few opportunities are given for work in a team and generally the work is personal and the work tasks in the group are for the short term (one or two lessons).	2, 3
	Teamwork of the student with the teacher	Receiving support and personal treatment between the teacher-mentor and the student (the entire research team has a close teacher-mentor for the entire inquiry work). This is expressed in that the teacher-mentor	It is difficult for the teacher in a large class to give personal treatment to every group. This is expressed in that the teacher is not always available for his students, there is no close follow-up	2, 3

		performs personal follow-up after the team of students and is more available to his students during the meeting than afterwards.	after the student's work during the lesson, and the teacher knows the situation of the class only after the test.	
		The teacher-mentor are partners in the investigation along with the students since for the most part the teacher-mentors do not know the answer to the inquiry question	The teacher for the most part knows the answers ahead of time for the laboratory activity and does not research with the students.	3
Identifying with the world of the scientific researcher	Learning resources – equipment, knowledge of the teacher-mentors to instruct inquiry, duration of time for the performance of the inquiry	In general, there is more exposure, closeness to the world of the scientist	There is less exposure to the world of the scientist/researcher.	2
		In research physics, there are means to perform a broad inquiry: an abundance of equipment, modern and sophisticated equipment, meaningful time for the performance of inquiry and teachers with experience to instruct inquiry.	In the school there are fewer means (equipment, time, expertise of teachers to instruct inquiry) in order to carry out a broad inquiry	3
	Style and aim of the experiment	Higher level of experiment, for different reasons; a long-term experiment because of the constant improvement of the experiment system and repeated experiments so as to achieve as much as possible more accurate results, complexity of the equipment – greater use of technological instruments and a computerized laboratory.	The level of the experiment is simpler, generally the experiment is performed one time during the year, they have at their disposal sparse and less sophisticated equipment.	2
		The results of the experiment are not known ahead of time, and there is even room for experiment results that are not expected (not commensurate with the theory) and constitute investigation, and there is a need to provide explanations of this gap.	For the most part, the results of the experiment are known ahead of time to the teacher / the student and generally the goal of the experiment and its conclusions are to confirm the theory learned in the classroom.	2, 3
		In general, there is more practical experience in the Research Physics Program than in the school.	In general, greater emphasis is placed on the learning of the theory than on the practical experience.	2, 3

It is possible to identify from the table the students' perception of the research physics learning environment, especially their perception of the learning resources (equipment, time, teacher-mentors for inquiry, and the roles of the teacher and the student in the different aspects: management of the inquiry work, building of the content knowledge, teamwork with the project partner and with the teacher, and in general to identify the students' perception of the work of the scientific researcher.

According to the students in the learning environment that focuses on an inquiry project, such as the Research Physics Program, the degree of independence of the student is great and the degree of involvement of the teacher-mentor / teacher in the laboratory activity is small (in comparison to the laboratory activity in the school framework). In the Research Physics Program, the student leads the inquiry project in all the inquiry stages – from the choice of the topic and its objectives, through the choice of way of investigation (planning and performing an experiment), to the collection and analysis of the findings. As a result, the student is more involved and active in the lesson than in the school framework. The student's responsibility for the learning in the inquiry project is very great. In addition, the student's self-regulation improves – the student in the learning environment focused on the inquiry project must manage and organize the work journal, handle complex challenges of decision making, learning from mistakes and failures, coping with situations of powerlessness and uncertainty (as expected from the inquiry process). The teacher-mentor's roles in this environment are to give to the student freedom of action and independence throughout the inquiry work, like enabling change of the inquiry objectives and reaching unexpected places because of the dynamism of the inquiry process and field of interest, to give time to the students to deal with challenges and not to immediately present the answer to the challenge. Alongside this, the teacher-mentor must provide support, encouragement, direction, and close follow up after the student's progress.

It can be seen from the table how the students characterize their learning and the building of the content knowledge during the inquiry work. In the students' opinion, the uniqueness of an environment focused on the inquiry project as done in the Research Physics program is that the practical experience (experiments in the laboratory) in most of the cases precedes the learning of the theory or is parallel to it. In other words, the building of knowledge is based first on the practical experience and on its basis the students learn

the theory. In addition, considerable independent learning of the theoretical content relevant to the inquiry is required, and the student in most of the process searches for sources of knowledge and builds his knowledge, alongside receiving support and direction from the teacher-mentor. In addition, unlike the school, in the Research Physics Program the students are not required to learn by heart and practice the formulas relevant to the researched topic, but for the most part they are given the time necessary to develop the formula, to understand its components, its goal, and how it is created. In addition, the students note that in this environment they are allowed to build the knowledge by themselves also in contents beyond the curriculum and they broaden their horizons and reach a profound understanding of the physical phenomenon researched in these contents.

The students notice another difference between the Research Physics framework and the framework of the school laboratory from the aspect of the teamwork between students and teamwork between students and teacher. In the inquiry project focused environment, many more opportunities are given to the teamwork between the students (in the Research Physics Program – work on the project is done in set pairs for two years). Therefore, this environment increased for the students the awareness of the importance of the teamwork. The students identify the advantages of teamwork, which leads to cooperative learning with the partner and mutual fertilization, division of labor, mutual commitment, joint decisions, receiving support from the partner, and development of interpersonal skills in the teamwork (such as giving help, consideration of the project partner's pace of learning, and listening and accepting opinions of the other person). The teacher-mentor's role in the teamwork is different also from the teacher's work in the school. The teacher-mentor provides support and a personal attitude to the student, which is expressed in the teacher-mentor's personal follow up after the team of his students and he is more available for his students. In addition, the teacher-mentor's status with the students is different from the status of the teacher in the school. In the framework of the program, in many situations the teacher-mentors are found at the students' eye level. The teacher-mentors are partners in the investigation, along with the students, since for the most part they also do not know the answer to the inquiry question.

In addition, the students noticed that the environment that focuses on the inquiry project is an environment similar to the world of the researcher/scientist: both in terms of the style and aim of the experiment – a higher level of experiment, for different reasons: a long-term experiment because of repeated experiments and constant improvement of the experiment system so as to achieve as much as possible accurate measurements, and the complexity of the equipment – more use of technological instruments and a computerized laboratory. The experiment results are not known ahead of time, and there is room in the program for experiment results that are not expected (which are not commensurate with the theory) and constitute investigation (there is a need to provide explanations for this gap). In terms of the learning resources – this environment enables the performance of a broader inquiry work since there are means for this; there is an abundance of equipment, the equipment that exists is modern and sophisticated, the duration of time for the performance of the inquiry is meaningful, and the teachers have the experience to instruct inquiry. In addition, the students note that in the Research Physics environment there is exposure as well as closeness to the world of the scientist/researcher as opposed to the school, mainly since they understand the nature of the inquiry process and the very experience of the considerable practical experience (many experiments in the laboratory) in the Research Physics program that give them the experience of “being a scientist”.

The following chapter presents, mainly from the interviews, further expressions of the students that address the differences between activities in the laboratory in the school framework and those in the Research Physics framework. In addition, the following chapter presents quantitative analyses from which it is possible to identify the students’ perception of the inquiry process and the learning environment focused on the inquiry projects.

4.2 The Students' Attitudes about the Inquiry Process and the "Research Physics" Learning Environment (Particularly the Roles of the Students and the Teachers and the Learning Resources)

This chapter presents quantitative and qualitative analyses of the findings of the **students' attitudes on the inquiry process, of the Research Physics learning environment** that focuses on the inquiry project. **Particularly the role of the student and the teachers and the learning resources given to them in this environment, their attitudes on their ability to perform inquiry work, and their attitudes on the contribution of the program to their personal growth** in these categories:

1. Management of the inquiry work (in the context of responsibility, independence, and initiative, planning and organization of the inquiry work, coping with the inquiry dynamism and with situations of uncertainty).
2. Building content knowledge (in the context of the student's active learning and independent learning).
3. Teamwork with the project partner and with peers in the broader group.
4. Identifying with the world of the scientific researcher

Every subchapter will present a quantitative analysis of the students' perception from two viewpoints, in general– how do they perceive the inquiry process generally in this aspect, and in actuality – how do they perceive the actual learning environment and the contribution of this environment. In addition, at the end of every subchapter a qualitative analysis will be presented from the interviews of 11 students out of 34 who are participating in the program, which were conducted after the end of the intermediate stage of the inquiry work (end of the eleventh grade), which address the perceptions presented in the quantitative findings.

4.2.1 The Students' Perception of the Aspect: Managing the Inquiry Work (in Stage 2 and Stage 3 of the Inquiry Work)

This subchapter refers to how students perceive the aspect of the management of the inquiry work in these sub-categories:

1. The student's responsibility for the inquiry work.
2. The student's independence and initiative in the inquiry work.
3. The planning and organization of the inquiry work (which includes order in the inquiry work, supervision, and meeting time schedule).
4. The coping with the dynamism of the inquiry and with situations of uncertainty during the inquiry work.

4.2.1.1 The Students' Perception of the Student's and Teacher-Mentor's Responsibility in the Inquiry Work (in Stage 2 and Stage 3 of the Inquiry Work)

4.2.1.1.1 The Students' Perception of Who Has the Responsibility for the Success of the Inquiry Project

This section presents the quantitative analysis of the students' perception of who has the responsibility for success of the project among those involved in the inquiry work, from the Attitudes Questionnaire (see Appendix 1.3). The questionnaire was held at two dates, during stage 2 – the intermediate stage of the inquiry work (in the middle of the eleventh grade, February 2018, N=33), and a year later during stage 3 – the final stage of the inquiry work (in the middle of the twelfth grade, January 2019, N=33), when there is a teacher-mentor close to every research team throughout the entire inquiry work.

In the questionnaire the students were asked to answer the question “In your opinion, who has the responsibility for the success of the inquiry project?” (from the list of people: student, teacher-mentor, laboratory technician, program developers, school physics teacher), when they have the possibility to indicate more than one answer.

The following figure presents the students' perception of who has the responsibility for the success of the inquiry project in the two stages of the inquiry work: the intermediate stage, in the middle of the eleventh grade school year, and the final stage, in the middle of the twelfth grade school year (from the Attitudes Questionnaire).

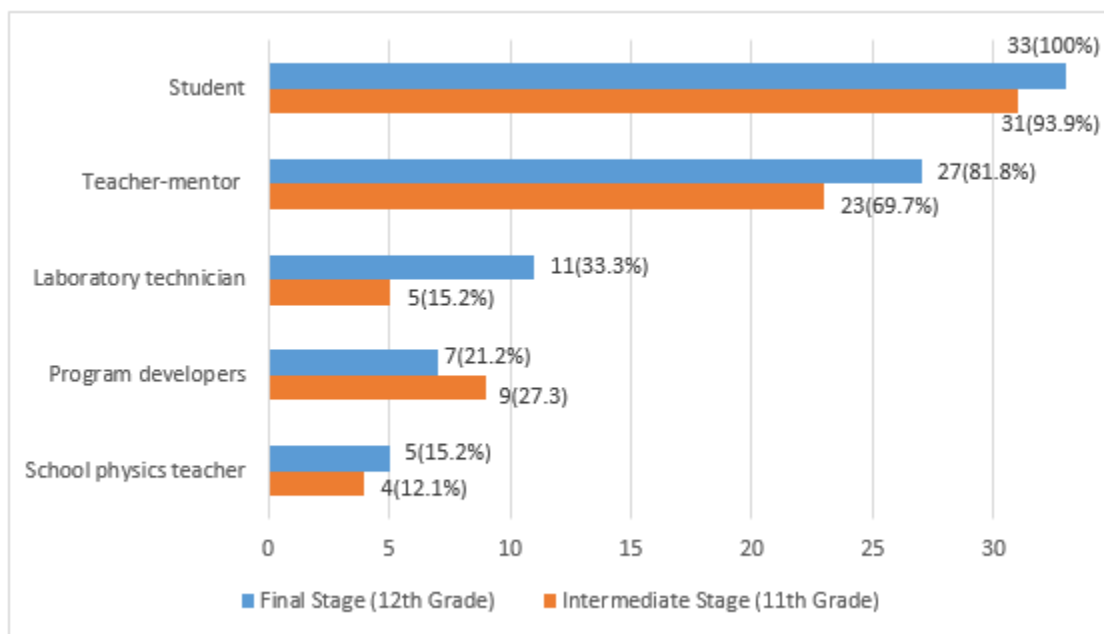


Figure 60: Report of the Students on Who Is Responsible for the Success of the Inquiry Project – Comparison of the Frequencies between the Intermediate Stage (N=33) and the Final Stage of the Inquiry Work (N=33)

It is possible to see from the above bar chart that according to the students:

- Most of the students indicated both in the intermediate stage and in the final stage that the main responsibility is assigned to the student and to the teacher-mentor. In the students' opinion, first and foremost, the responsibility for the project success is on them (93.9% in the intermediate stage, 100% in the final stage), then the teacher-mentor (69.7% in the intermediate state, 81.8% in the final stage), and then the rest of the people who are involved in the success of the inquiry project (laboratory technician, Program developers, school physics teacher).
- There is a trend of increase in the percentage who indicated the laboratory technician with regard to the responsibility for the success of their inquiry project from the intermediate stage (15.2%) to the final stage (33.3%). This increases the importance of the laboratory technician in the students' success in the inquiry project (still most of the students chose the student and the teacher-mentor). The rise in the percentage indicates a change in the students' perception of the profession of laboratory technician, who provides them with equipment but also

has an important part in the success of the inquiry process. Indeed, in the structure of intervention of the program and in the view of the observation, the laboratory technician was a part of the staff of program teacher-mentors, who suggested ideas and directions of investigation to the students and the teacher-mentors, suggested improvements to the students' experiments, and accordingly obtained the required equipment and helped the students who had encountered difficulties during the sessions.

- The physics teacher in the school was selected the least. According to the structure of the intervention, the physics teacher of the school was not involved in the process of the inquiry work with the students (the students worked with teacher-mentors who do not belong to their school), but is responsible to register the students to the program and to see to organizational needs, such as transportation and follow-up after students to reach the institute.
- There are no significant differences ($p > .05$) between the intermediate stage (eleventh grade) and the final stage of the inquiry work (twelfth grade) in each one of those involved for the success of the inquiry project.

4.2.1.1.2 The Students' Perception of the Degree of Responsibility of the Student and the Teacher-Mentor in the Inquiry Work

This section focuses only on the students' perception of the degree of responsibility of the student and the teacher. In the continuation of the questionnaire, the students were asked to answer the question "Write what is the degree of responsibility for the success of project of the student / teacher-mentor", when the student needed to choose from a scale 1-5 (when 1 – not responsible at all, 5 – greatly responsible).

The following figure presents the students' perception of the degree of responsibility of the student / teacher in the inquiry work – comparison of the means between the intermediate stage in the middle of the eleventh grade school year and the final stage of the inquiry work in the middle of the twelfth grade school year (from the Attitudes Questionnaire, see Appendix 1.3).

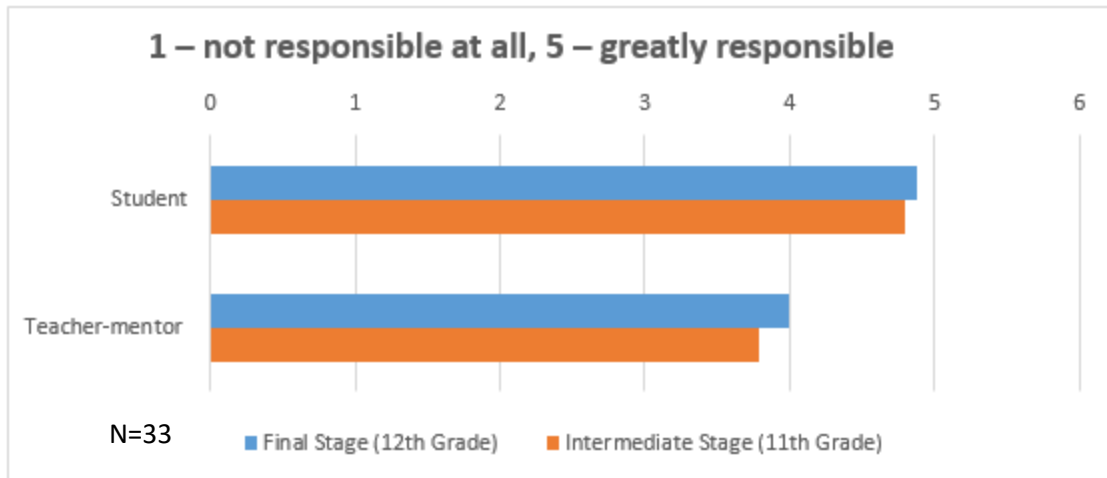


Figure 61: Report of the Students of the Degree of Responsibility for the Success of the Project of the Student and the Teacher-Mentor – Comparison of the Means between the Intermediate Stage (N=33) and the Final Stage of the Inquiry Work (N=33)

It is possible to see from the above bar chart that:

- Like the previous figure, here too both in the intermediate stage and in the final stage of the inquiry work the students report that they take considerable responsibility for the success of the inquiry project (mean very close to the value of 5). The student's degree of responsibility is greater than the teacher-mentor's degree of responsibility. However, the teacher-mentor also has a high degree of responsibility (mean very close to the value of 4).

4.2.1.1.3 *The Responsibility for the Inquiry Work in General and the Actual Learning Environment according to the Students*

This subchapter presents the quantitative findings of the self-reporting questionnaires held at four points of time. Time points: Middle of eleventh grade: February 2018/ End of eleventh grade: April 2018/ Middle of twelfth grade: January 2019/ End of twelfth grade: May 2019. The students (N=33) were asked to address the role of the student and the teacher in the aspect of the management of the inquiry work, in the context of the responsibility for the inquiry work, from two perspectives: in general– how do they perceive the inquiry process generally in this aspect, and in actuality – how do they perceive the actual learning environment and the contribution of this environment.

In this section, the questions are Likert scale (from Attitudes Questionnaire & Summative Questionnaire, see in Appendix 1.3 & 1.4), in which the student is asked to indicate the degree to which he agrees with different statements on a scale of 1-5 (1 – not at all, 5 – greatly).

The following table presents the findings (reader: $\langle \rangle$ =mean, σ = standard deviation):

Table 16: The Students’ Perception of the Responsibility for the Inquiry Work in General and the Actual Learning Environment (N=33) (Sigron, M)

Time Point	Intermediate Stage of the Inquiry Work		Final Stage of the Inquiry Work		$\Delta \langle \rangle$	$\Delta \sigma$	Pr > t	$\Delta \langle \rangle$	$\Delta \sigma$	Pr > t
	Middle 11 th February 2018	End 11 th April 2018	Middle 12 th January 2019	End 12 th May 2019						
Source of information - questionnaire	Attitudes	Summative	Attitudes (Repeat)	Summative (Repeat)	Attitudes			Summative		
Perception of the inquiry process in general	$\langle \rangle = 3.3^{30}$ $\sigma = 0.75$		$\langle \rangle = 3.27$ $\sigma = 0.79$		-0.03	0.71	0.81			
Perception of the learning environment in actuality		$\langle \rangle = 4.25^{31}$ $\sigma = 0.6$		$\langle \rangle = 4.08$ $\sigma = 0.56$				-0.17	0.63	0.13
Perception of the contribution of the learning environment	$\langle \rangle = 4^{33}$ $\sigma = 0.9$	$\langle \rangle = 4.21^{32}$ $\sigma = 0.96$	$\langle \rangle = 4.12$ $\sigma = 1.13$	$\langle \rangle = 4.27$ $\sigma = 0.88$	0.12	1.15	0.18	0.06	1.27	0.79

- Perception of the inquiry process in general. Both in the intermediate stage and in the final stage of the inquiry, the students agree to a certain degree but not completely (values between 3 and 3.5) that the degree of responsibility for the learning in the way of inquiry and for the performance of the work is not only the student and not only the teacher-mentor’s but belongs to both to a certain degree. (In the previous

³⁰ Statements: Responsibility for the learning in the way of inquiry and for the performance of the work is that of the student alone, the teacher is the main source of information in learning through inquiry (opposite statement).

³¹ Statements: Responsibility for the inquiry process in the project was primarily that of the student, the inquiry project required responsibility and considerable commitment, the responsibility for the inquiry process in the project was mainly on the teacher (opposite statement).

³² Statement: The program contributed to the development of improvement on the issue: personal responsibility for learning and for performance of good work.

³³ Statement: Performance of inquiry activities cultivates my responsibility for the learning and for the performance of the work required in the inquiry work.

- subsection it was possible to see more the division of responsibility between the student and the teacher-mentor, where it is possible to see clearly that according to the students the student's responsibility is greater than that of their teacher-mentor.)
- Perception of the learning environment in actuality. Both in the intermediate stage and in the final stage of the inquiry, the students agree (values between 4 and 4.5) that experiences in inquiry activity that required responsibility and considerable commitment on the part of the student and the responsibility for the inquiry process in the project was primarily of the student.
 - Perception of the contribution of the learning environment. Both in the intermediate stage and in the final stage of the inquiry, the students agree (values between 4 and 4.5) that the experiences in the inquiry activity in the program contributed to the cultivation of their personal responsibility for the learning and for the performance of good work, as required in the inquiry work.
 - Comparison of perceptions between in general and in actuality. Both in the intermediate stage and the final stage of the inquiry the students' perception of their degree of responsibility in the inquiry work in retrospect, after the experience in actuality, was higher than their perception initially, and this is commensurate with their view of the contribution of the experience to the cultivation of their responsibility for the learning.

4.2.1.1.4 Qualitative Analysis from the Interviews

This section presents examples of quotes from interviews performed after the submission of the intermediate report at the end of the eleventh grade for the question that addresses the students' perception of their degree of responsibility and that of the teacher-mentor for the success of the inquiry project: who do you think has more responsibility for the learning and for the success of the project – the teacher-mentor or the student?

Table 17: Quotes from the Interviews for the Question: “Who do you think has greater responsibility for learning and success of the project – the teacher-mentor or the student?”

Responsibility More on the Teacher-Mentor	Responsibility More on the Student
Student 10, F: “More on the teacher-mentor, I think, I saw from other groups that they complained mainly about the teacher, so it is possible to say that this is rather equal but a drop more about the teacher-mentor.”	Student 14, M: “I think that the responsibility is assigned both to the students and to the teacher-mentors. We all take part in the project and its success. But I think about the students more. Since the teacher-mentor only needs to instruct us and the students in the end need to do, to read, to research, to build, to collect. If the students are serious, this will happen. The teacher-mentor cannot do the work instead of us. If the students are not serious, then the inquiry work will not progress. ”
	Student 12, F: “Both the student and the teacher-mentor are responsible for the project success. The student’s responsibility is 70% and the teacher-mentor’s responsibility is 30%. But without the teacher-mentor’s help in the theory and planning they would not reach a high level in the project and not advance in the project, but without the student’s responsibility to do things and to work – this would not succeed. ”
	Student 15, M: “Most of the responsibility is on the students, 70%-80% on the student, and the rest on the teacher-mentor we had. He was not supposed to do most of the work. The teacher-mentor only is supposed to help us advance and to develop new ways of thinking. And to help us understand material that perhaps we did not know. The main work needs to be on us, to work and to research at home. ”
	Student 13, M: “I think that the students need more to take responsibility since this is still their project, the teacher-mentor does need to be involved, does need to help, but this is still the students’ project. In other words, the teacher-mentor needs to be the listener, to help, but he cannot take upon himself the project. The students need to divide their time, to be sure that the meetings will be in the afternoon, and if in these meetings they need help then the teacher-mentor needs to be involved and to help but he does not need to make sure that the project will stand, this is the student’s responsibility. ”
	Student 17, F: “The responsibility is the student’s and the teacher-mentor’s, 70% the student’s, the student needs to understand that if he does not do and learn independently then it will not succeed. The teacher-mentor directs but the responsibility is on the student.”
	Student 9, M: “The responsibility for the learning is that of the student and it is significant. I think first about the students and then the teacher-mentor. 60% us, 30% the teacher-mentor, 10% the different people accompanying the program.”
	Student 8, M: “I think that the responsibility of the students more, 70% is that of the students. In the end, the student invests, if he does not invest, then there will be no project.”

It is possible to see from the interviews (from the quotes presented in the table) that here too the students' perception was prominent that the responsibility for the project success is placed on them more than on the teacher-mentors, since otherwise the inquiry work would not be meaningful and full. However, the teacher-mentor's responsibility is essential and very important to the success of the project, since with his help the inquiry project advances and the nature of the project is improved. In addition, from the explanations of some of the students for the answer it is possible to learn about the areas of responsibility assigned to the student and the teacher-mentor. The student's responsibility is primarily operational, from making the time and organizing the work to performing it, while the teacher-mentor's responsibility is primarily to provide an answer to the problems the students cannot answer by themselves, to provide a supra-picture with regard to theory and planning, direction, and support as necessary.

In addition, it can be seen in the students' quotes that shown in Appendix 4.2.1 (examples A, B) that some students said that following the experience in the inquiry work they improved their degree of responsibility for their learning. The responsibility is expressed in their concern that the project will be ready and will reach its end and will be on the level required in the program. To do this, they are required to be serious, to have self-discipline, to invest greatly, and to do the best that they can. Alongside this, some of the students (in Appendix 4.2.1, example C) said that from the beginning they had a high level of responsibility even before the program.

4.2.1.2 The Students' Perception of the Student's Degree of Independence and the Teacher-Mentor's Degree of Involvement in the Inquiry Work (in Stage 2 and Stage 3 of the Inquiry Work)

4.2.1.2.1 The Degree of Independence and Initiative in the Performance of the Inquiry in General and the Actual Learning Environment according to the Students

This subchapter presents the quantitative findings of the self-reporting questionnaires that were held at four points of time. Time points: Middle of eleventh grade: February 2018/ End of eleventh grade: April 2018/ Middle of twelfth grade: January 2019/ End of twelfth grade: May 2019. The students (N=33) were asked to address the role of the

student and the teacher in the aspect of the management of the inquiry work, in the context of the student's degree of independence and initiative and the teacher's degree of involvement in the inquiry work, from two viewpoints: in general– how do they perceive the inquiry process generally in this aspect, and in actuality – how do they perceive the actual learning environment and the contribution of this environment.

In this section, the questions are Likert scale (from Attitudes Questionnaire & Summative Questionnaire, see in Appendix 1.3 & 1.4), in which the student is asked to indicate the degree to which he agrees with different statements on a scale of 1-5 (1 – not at all, 5 – greatly).

The following table presents the findings (reader: $\langle \rangle$ =mean, σ = standard deviation):

Table 18: The Students' Perception of the Degree of Independence and Initiative in General and the Actual Learning Environment (N=33)

Time Point	Intermediate Stage of the Inquiry Work		Final Stage of the Inquiry Work		$\Delta \langle \rangle$	$\Delta \sigma$	Pr > t	$\Delta \langle \rangle$	$\Delta \sigma$	Pr > t
	Middle 11 th February 2018	End 11 th April 2018	Middle 12 th January 2019	End 12 th May 2019						
Information source: questionnaire	Attitudes	Summative	Attitudes (Repeat)	Summative (Repeat)	Attitudes			Summative		
Perception of the inquiry process in general	$\langle \rangle = 3.26^{34}$ $\sigma = 0.86$		$\langle \rangle = 3.49$ $\sigma = 0.87$		0.23	0.17	0.2			
Perception of the learning environment in actuality	$\langle \rangle = 4.18^{36}$ $\sigma = 0.68$	$\langle \rangle = 4.54^{35}$ $\sigma = 0.56$	$\langle \rangle = 4$ $\sigma = 0.87$	$\langle \rangle = 4.30$ $\sigma = 0.73$	-0.18	0.73	0.16	-0.24	0.94	0.15
Perception of the contribution of the learning environment	$\langle \rangle = 4^{38}$ $\sigma = 0.73$	$\langle \rangle = 4.30^{37}$ $\sigma = 0.81$	$\langle \rangle = 4.12$ $\sigma = 0.64$	$\langle \rangle = 4.21$ $\sigma = 0.70$	0.12	0.89	0.29	-0.09	0.91	0.57

³⁴ Statements: The inquiry is characterized by a minimum of instruction and direction on the part of the teacher/teacher-mentor, the student's degree of independence needs to be maximal in all the inquiry stages.

³⁵ Statement: The inquiry process necessitated the student's considerable independence and initiative.

³⁶ Statement: In the performance of inquiry activities I felt an opportunity to do something in an independent and experiential manner.

³⁷ Statement: The program contributed to the development or improvement on the issue of the cultivation of independent and initiative.

³⁸ Statement: The performance of the inquiry activities trained me to have independent ability, the performance of inquiry activities enabled the cultivation of the student's initiative.

- Perception of the inquiry process in general: Both in the intermediate stage and in the final stage of the inquiry, the students agree to a certain degree, but not completely (values between 3 and 3.5) that learning through inquiry is characterized by a minimum of instruction and direction on the part of the teacher/teacher-mentor and the student's degree of independence needs to be maximal in all stages of the inquiry.
- Perception of the learning environment in actuality. Both in the intermediate stage and in the final stage of the inquiry, the students agree (values between 4 and 4.5) that they experienced independent in the performance of the inquiry activities in the program and that the inquiry process necessitated the student's considerable initiative.
- Perception of the contribution of the learning environment. Both in the intermediate stage and in the final stage of the inquiry, the students agree (values between 4 and 4.5) that the experiences in the inquiry activity enabled the cultivation of the student's initiative.
- Comparison of perceptions between in general and in actuality. Both in the intermediate stage and in the final stage of the inquiry, the students' perception of their degree of independence and initiative in the inquiry work in retrospect, after the actual experience, was higher than their perception from the beginning, and this is commensurate with their view of the contribution of the experience to the cultivation of the independence and initiative in the performance of the inquiry.

4.2.1.2.2 Qualitative Analysis from Interviews

From the interviews, that were held after the submission of the intermediate report at the end of the 11th grade, it is possible to see the students' perception on the issue of the student's degree of independence and initiative and the teacher-mentor's degree of involvement in the inquiry work (Appendix 4.2.2 presents examples of student quotes from the interviews), primarily from the following questions:

1. What in your opinion is the uniqueness of the research physics program?

2. Describe your teamwork with the teacher-mentor. What do you think about / describe the teacher-mentor's degree of involvement?
3. Did the program improve your self-efficacy (belief in yourself) to do things independently/alone?
4. With what are you satisfied in the program? With what are you not satisfied?

The structure of the program dictates not only the students' attitude but also the difference in the teacher-mentors' approaches. The prominent thing is that the students in any case are interested in independence: the students are satisfied when the teacher-mentors give independence and room for their decision and are frustrated when the situation is reversed, even if their project succeeded.

In appendix 4.2.2 (Examples A-D) present the students' quotes which describe the involvement of the teacher-mentor who gives the space of action to the students during the inquiry and gives the students independence in the inquiry work and does not limit the students both in conceptual terms and in practical terms in the laboratory. These students greatly liked this approach and were satisfied and saw the necessity of this approach to the research work (also in the continuation for the future). Other examples (Examples E-G in appendix 4.2.2) present the quotes of the students who describe the involvement of the teacher-mentor who less gives them independence during the performance of the inquiry process (or gives them only towards the end of the research) and they are not satisfied with this and would be interested in this approach changing. Alongside the importance of giving independence to the student in the inquiry work, it is important to the students to also receive close accompaniment and personal reference from their teacher-mentor (this perception is prominent primarily in example H in appendix 4.2.2).

Another thing: Here too the "what" is more important than the "whether". In other words, from the students' responses themselves it is possible to see that they focus the term of independence on the aspects as follows (Appendix 4.2.2 presents examples illustrating these aspects):

1. Freedom of action in the practical experience, like the organization of the experiment equipment, planning the experiment, and performing the experiment independently.
2. Ownership of the making of decisions on the directions of development of the project.

- Giving time and space to the students in doing and planning the experiments and the work alongside advice when necessary.
- Giving an equal status to the student and to the teacher-mentor in the resolution of disagreements on different aspects in the project.
- The student's desire has a decisive weight in the directions of development of the project.
- Semi-open inquiry – the teacher-mentor does not give answers, that he knows, but requires them to discover them by themselves.

Regarding the aspect of their self-efficacy to do things independently, few students answered this and among those who answered a central thing that arises is their early self-perception – they see themselves as having from the beginning high self-efficacy but this depends on the teacher-mentor – either it is possible or it is not possible for this to be expressed.

4.2.1.3 The Students' Perception of the Planning and Organization of the Inquiry Work (in Stage 2 and Stage 3 of the Inquiry Work)

4.2.1.3.1 Planning and Organizing the Inquiry Work in General and the Actual Learning Environment according to the Students

This subchapter presents the quantitative findings of the self-reporting questionnaires held at four time points. Time points: Middle of eleventh grade: February 2018/ End of eleventh grade: April 2018/ Middle of twelfth grade: January 2019/ End of twelfth grade: May 2019. The students (N=33) were asked to address the student's role in the aspect of the management of the inquiry work, in the context of planning and organizing the inquiry work (which includes order in the inquiry work, supervision, and meeting the time schedule), from two perspectives: in general– how do they perceive the inquiry process generally in this aspect, and in actuality – how do they perceive the actual learning environment and the contribution of this environment.

In this section, the questions are Likert scale (from Attitudes Questionnaire & Summative Questionnaire, see in Appendix 1.3 & 1.4), in which the student is asked to indicate the degree to which he agrees with different statements on a scale of 1-5 (1 – not at all, 5 – greatly).

The following table presents the findings (reader: $\langle \rangle$ =mean, σ = standard deviation):

Table 19: The Students' Perception of the Planning and Organization of the Inquiry Work in General and the Actual Learning Environment (N=33)

Time Point	Intermediate Stage of the Inquiry Work		Final Stage of the Inquiry Work		$\Delta \langle \rangle$	$\Delta \sigma$	Pr > t	$\Delta \langle \rangle$	$\Delta \sigma$	Pr > t
	Middle 11 th February 2018	End 11 th April 2018	Middle 12 th January 2019	End 12 th May 2019						
Source of information: questionnaire	Attitudes	Summative	Attitudes (repeat)	Summative (repeat)	Attitudes			Summative		
Perception of the inquiry process in general	$\langle \rangle = 3.87^{39}$ $\sigma = 0.89$		$\langle \rangle = 4.13$ $\sigma = 0.92$		0.26	1	0.16			
Perception of the learning environment in actuality	$\langle \rangle = 4^{40}$ $\sigma = 0.67$		$\langle \rangle = 4.23$ $\sigma = 0.57$		0.23	0.94	0.17			
Perception of the contribution of the learning environment		$\langle \rangle = 4.18^{41}$ $\sigma = 1.0$		$\langle \rangle = 4.36$ $\sigma = 0.67$				0.18	1.07	0.34
		$\langle \rangle = 4.06^{42}$ $\sigma = 0.93$		$\langle \rangle = 3.88$ $\sigma = 1.11$				-0.18	1.07	0.34

- Perception of the inquiry process in general. The students agree (values close to the value of 4) both in the intermediate stage and in the final stage of the inquiry that it is necessary to look at the process of learning through inquiry and at the management of the inquiry in a critical manner, including planning and organization of the inquiry work and making sure to meet the time schedules.
- Perception of the learning environment in actuality. Both in the intermediate stage and in the final stage of the inquiry, the students agree (values between 4 and 4.5) that in the inquiry activities they are required to organize the work and to plan the time at their disposal so as to meet the time schedule.

³⁹ Statement: The process of scientific inquiry is not complete without looking at it critically, including the planning and organizing of the inquiry work and the adhering to the time schedule.

⁴⁰ Statements: In the performance of the inquiry activities I was required to meet the time schedule and to be organized in the work, performance of the inquiry activities required considerable time and time planning.

⁴¹ Statements: The program contributed to the development/improvement in the issue of ability of planning and organizing the work.

⁴² Statements: The program contributed to the development/improvement in the issue of critical and reflective thinking on the inquiry work.

- Perception of the contribution of the learning environment. Both in the intermediate stage and in the final stage of the inquiry, the students agree (values close to the value of 4) that the experiences in the inquiry activity in the program contributed to the development/improvement of the ability of planning and organization of the work and the critical and reflective thinking on the inquiry work.
- Comparison of perceptions between in general and in actuality. Both in the intermediate stage and in the final stage of the inquiry, the students' perception of the planning and the organization of the inquiry work after the experience in actuality was commensurate with their perception from the beginning. This is commensurate with their view of the contribution of the experience to the improvement of the practice of management of the inquiry work – the ability of planning and organization of work and the insights in the inquiry process in a critical and reflective way.

4.2.1.3.2 *Qualitative Analysis from Interviews*

From the interviews, that were held after the submission of the intermediate report at the end of the 11th grade, it is possible to see students' perception on the issue of the management of the inquiry work in the context of the planning and organization of the inquiry work (Appendix 4.2.3 presents examples of student quotes from the interviews), mainly from the following questions:

1. What were your difficulties in the program? How did you cope with them? Tell me about the challenges you experienced in the project?
2. What would you like to improve or strengthen next year?
3. What did you learn from the program about yourself? What did the program contribute to you in the personal aspect?
4. What tip would you give to a new student who comes to the program?

According to the students, the improvement of the planning and organization of the inquiry work is expressed in the main aspects as follows (Appendix 4.2.3 presents examples illustrating these aspects):

1. The use of instruments for the planning and supervision of the inquiry work – through a work journal that helps to document what is done and to write the planning of the work and the time schedule and enables follow up and supervision of the work.
2. The taking of responsibility and the making of time to meet the time schedule.
3. The performance of order and organization in the inquiry work in an ongoing and constant manner.
4. The independent conduct alongside the counseling with the teacher-mentor for the purpose of getting help in the planning and organization of the research and the setting of objectives for the coming meetings.

4.2.1.4 The Students' Perception of the Coping with the Dynamism of the Inquiry and with Situations of Uncertainty in the Inquiry Work (in Stage 2 and Stage 3 of the Inquiry Work)

4.2.1.4.1 The Coping with the Dynamism of the Inquiry and Situations of Uncertainty during the Inquiry Work in General and the Actual Learning Environment according to the Students

This subchapter presents the quantitative findings of the self-reporting questions distributed at four points of time. Time points (N=33): Middle of eleventh grade: February 2018/ End of eleventh grade: April 2018/ Middle of twelfth grade: January 2019/ End of twelfth grade: May 2019. The students (N=33) were asked to address the student's role in the aspect of management of the inquiry work, in the context of coping with the dynamism of inquiry and with situations of uncertainty during the inquiry work, from two viewpoints: in general– how do they perceive the inquiry process generally in this aspect, and in actuality – how do they perceive the actual learning environment and the contribution of this environment.

In this section, the questions are Likert scale (from Attitudes Questionnaire & Summative Questionnaire, see in Appendices 1.3, 1.4), in which the student is asked to indicate the degree to which he agrees with different statements on a scale of 1-5 (1 – not at all, 5 – greatly).

The following table presents the findings (reader: $\langle \rangle$ =mean, σ = standard deviation):

Table 20: The Students' Perception of the Coping with the Dynamism of the Inquiry and with Situations of Uncertainty during the Inquiry Work in General and the Actual Learning Environment (N=33)

Time Point	Intermediate Stage of the Inquiry Work		Final Stage of the Inquiry Work		$\Delta \langle \rangle$	$\Delta \sigma$	Pr > t	$\Delta \langle \rangle$	$\Delta \sigma$	Pr > t
	Middle 11 th February 2018	End 11 th April 2018	Middle 12 th January 2019	End 12 th May 2019						
Source of information: Questionnaire	Attitudes	Summative	Attitudes (Repeat)	Summative (Repeat)	Attitudes			Summative		
Perception of the inquiry process in general	$\langle \rangle = 3.93^{43}$ $\sigma = 0.40$		$\langle \rangle = 4.17$ $\sigma = 0.38$		0.25	0.51	0.0086			
	$\langle \rangle = 4.36^{44}$ $\sigma = 0.82$		$\langle \rangle = 4.45$ $\sigma = 0.67$		0.09	0.91	0.57			
Perception of the learning environment in actuality	$\langle \rangle = 4.09^{46}$ $\sigma = 0.56$	$\langle \rangle = 4.28^{45}$ $\sigma = 0.55$	$\langle \rangle = 4.18$ $\sigma = 0.57$	$\langle \rangle = 4.33$ $\sigma = 0.55$	0.09	0.61	0.40	0.05	0.72	0.72
Perception of the contribution of the learning environment		$\langle \rangle = 4.14^{47}$ $\sigma = 0.86$		$\langle \rangle = 4.28$ $\sigma = 0.64$				0.14	1.13	0.48
		$\langle \rangle = 4.39^{48}$ $\sigma = 0.86$		$\langle \rangle = 4.39$ $\sigma = 0.9$				0.00	1.06	1

⁴³ Statements: The research is dynamic – directions of investigation and ways of inquiry can change during the work process. The inquiry process is composed of stages related to one another and the transition between them is a network and sometimes there is a return to certain stages, a mistake, and search for the solution is an opportunity for learning and it is a natural part of the research process. The scientific inquiry process is composed of stages in a regular chronological order (for example in this order: choosing a topic, recognizing the existing knowledge on the researched topic, asking questions, phrasing the inquiry question, raising a hypothesis, planning and performing an experiment, processing the findings, drawing conclusions, presenting results) – (opposite statement), the scientific researcher works exactly according to his planning when performing the research (opposite statement). In research a mistake is failure (opposite failure).

⁴⁴ Statement: The inquiry question is dynamic and can change with the progress of the research stages.

⁴⁵ Statements: During the performance of the project I experienced many frustrations but with progress of the work the I understood more the topic in scientific terms and I learned that the perseverance and stubbornness are important during the inquiry work, following the experience I believe that every additional inquiry project poses new difficulties that should be coped with.

⁴⁶ Statements: The performance of inquiry activities requires ability to adjust to coping with changes, in the performance of inquiry activities, I coped with conditions of uncertainty, performance of inquiry activities set for me required traits of persistence and devotion to the purpose, performance of inquiry activities was not effective in learning since they do not advance in an orderly manner and sometimes “they get lost” (opposite statement).

⁴⁷ Statements: The program contributed to the development / improvement on the issue of resilience and flexibility in coping with difficulties, coping under conditions of uncertainty, coping in situations of powerlessness/frustration.

⁴⁸ Statements: The program contributed to the development/improvement in the issue of creative thinking in order to solve problems that appear during the inquiry and in order to leave a situation of uncertainty or powerlessness.

		$\langle \rangle = 4.49^{49}$ $\sigma = 0.62$		$\langle \rangle = 4.61$ $\sigma = 0.55$				0.12	0.82	0.40
--	--	--	--	---	--	--	--	------	------	------

- Perception of the inquiry process in general. The students agree (values between 4 and 4.5) both in the intermediate stage and in the final stage of the inquiry that the research is a dynamic process, when the directions of investigation and the ways of inquiry can change during the work. Coping with the dynamism of the inquiry, with the mistakes and search for the solution, is an opportunity for learning and a natural part of the research process. There is even a significant increase in this perception (statement 43) between the intermediate stage and the final stage of the inquiry work.
- Perception of the learning environment in actuality. Both in the intermediate stage and in the final stage of the inquiry, the students agree (values between 4 and 4.5) that they coped with the dynamism of the inquiry and experienced coping with conditions of uncertainty and frustrations. To overcome these challenges, the students required traits of perseverance and dedication to the goal and ability to adjust to changes. During the inquiry they learned that perseverance and stubbornness are importance to the advancement and performance of the research work.
- Perception of the contribution of the learning environment. Both in the intermediate stage and in the final stage of the inquiry, the students agree (values between 4 and 4.5) that the experiences in the inquiry activity in the program contributed to the development/improvement of aspects related to self-regulation, such as resilience and flexibility in the coping with situations of uncertainty and with frustrations and the development of creative thinking in the solving of problems that appear during the inquiry and to overcome the situation of uncertainty or powerlessness. Moreover, both in the intermediate stage and in the final stage of the inquiry, the students agree greatly (close to the value of 4.5) since they feel they can cope with a new inquiry project with relative ease.

⁴⁹ Statement: Following the experience I feel that I can more easily cope with a new inquiry project.

- Comparison of perceptions between in general and in actuality. Both in the intermediate stage and in the final stage of the inquiry, the students' perception of the coping with the dynamism of the inquiry and with situations of uncertainty during the inquiry work after the experience in actuality was commensurate with their perception from the beginning. This is commensurate with their view of the contribution of the experience to the improvement of the ability of coping with these challenges.

4.2.1.4.2 *Qualitative Analysis from Interviews*

From the interviews, that were held after the submission of the intermediate report at the end of the 11th grade, it is possible to see the students' perception in the issue of the management of inquiry work in the context of coping with dynamism of the inquiry and with situations of uncertainty during the inquiry work (Appendix 4.2.4 presents examples of student quotes from the interviews), mainly from the following questions:

1. Tell me about the challenges that you have experienced in the project. How did you cope with them?
2. Did you experience a breaking point /frustration during the project? Or a situation of lack of powerlessness / uncertainty? And how did you overcome this?
3. Did you develop creativity in the program? How was this expressed?
4. What did you learn from the program about yourself? What did the program contribute to you in the personal aspect?
5. What tip would you give to a new student who comes to the program?
6. Do you feel that you can do further inquiry work?

It is possible to see from the interviews that the Research Physics Program offered for the students challenges such as coping with the dynamism of inquiry and with situations of uncertainty during the inquiry work. To overcome these challenges, the students improved their self-regulation in this issue.

The main aspects that arise from the students' statements on the issue of the coping with the dynamism of the inquiry and with situations of uncertainty during the inquiry work are as follows (Appendix 4.2.4 presents examples illustrating these aspects):

A. Change of Conduct and Perception

1. Reading and understanding that these copings (dynamism, lack of certainty, ‘dead end’, and ‘failures’) are a natural part of the inquiry process.
2. Development of the adjustment ability (resilience and flexibility) to the situations of uncertainty and dynamism during the inquiry work.
3. Recognition that the determination and persistence enable leaving what appears as a dead end.
4. Development of creative thinking to solve problems that appear during the inquiry and to leave a situation of uncertainty or powerlessness and to bring up new ideas and original solutions.

B. Change in the perception of the self-efficacy

1. The reduction of the fear of coping with new things or “failures” (in the student’s opinion).
2. Belief in themselves that they can perform inquiry work and cope with the difficulties caused by the inquiry.

In addition, some of the students note the importance of the teacher-mentors’ support and direction as needed and especially in situations of powerlessness and frustration, through observation and joint reflection on what is done and on shared decisions about what to focus on, giving hints and suggestions on ways of investigation, including encouragement and motivation to continue to advance in the investigation. In addition, the teacher-mentors give the students the confidence to be in situations of uncertainty or lack of comfort with the dynamism of the inquiry or with “failure” (in the students’ opinion), which are an inseparable part of the inquiry process. This is from giving a personal attitude and creating relationships of trust and openness with the students. It is possible to see that some of students (see appendix 4.2.4 examples I, J) are frustrated when they do not receive the support they need, especially when they have reached a “dead end”.

4. 2.2 The Students' Perception of the Aspect: Building Content Knowledge in the Inquiry Work (in Stage 2 and Stage 3 of the Inquiry Work)

In this subchapter, we address how the students perceive the aspect of building content knowledge in the inquiry work in the context of the student's active learning and independent learning and understanding the content relevant to the inquiry in-depth.

4.2.2.1 Building Content Knowledge in General and the Actual Learning Environment according to the Students (in Stage 2 and Stage 3 of the Inquiry Work)

This subchapter presents the quantitative findings about the self-reporting questionnaires held at four points of time. Time points (N=33): Middle of eleventh grade: February 2018/ End of eleventh grade: April 2018/ Middle of twelfth grade: January 2019/ End of twelfth grade: May 2019.

The students (N=33) were asked to address the student's role in the aspect of building content knowledge, in the context of the student's active learning and independent learning in the inquiry work (in which the student is involved and active in learning and builds his knowledge), broadening the knowledge and understanding the content relevant to the inquiry and its depth, from the two viewpoints: in general– how do they perceive the inquiry process generally in this aspect, and in actuality – how do they perceive the actual learning environment and the contribution of this environment.

In this section, the questions are Likert scale (from Attitudes Questionnaire & Summative Questionnaire, see in Appendices 1.3, 1.4), in which the student is asked to indicate the degree to which he agrees with different statements on a scale of 1-5 (1 – not at all, 5 – greatly).

The following table presents the findings (reader: $\langle \rangle$ =mean, σ = standard deviation):

Table 21: The Students' Perception of the Building Content Knowledge in General and the Actual Learning Environment (N=33)

Time Point	Intermediate Stage of the Inquiry Work		Final Stage of the Inquiry Work		$\Delta\langle$	$\Delta\sigma$	Pr > t	$\Delta\langle$	$\Delta\sigma$	Pr > t
	Middle 11 th February 2018	End 11 th April 2018	Middle 12 th January 2019	End 12 th May 2019						
Information source: Questionnaire	Attitudes	Summative	Attitudes (Repeat)	Summative (Repeat)	Attitudes			Summative		
Perception of the inquiry process in	$\langle = 4.31^{50}$ $\sigma = 0.93$		$\langle = 4.53$ $\sigma = 0.62$		0.22	0.94	0.2			
Perception of the learning environment in actuality	$\langle = 4.30^{51}$ $\sigma = 0.88$		$\langle = 4.42$ $\sigma = 0.56$		0.56	0.82	0.4			
	$\langle = 4.33^{53}$ $\sigma = 0.82$	$\langle = 4.76^{52}$ $\sigma = 0.50$	$\langle = 4.39$ $\sigma = 0.79$	$\langle = 4.61$ $\sigma = 0.61$	0.06	0.79	0.66	-0.15	0.79	0.28
Perception of the contribution of the learning environment		$\langle = 4.12^{54}$ $\sigma = 0.93$		$\langle = 4.09$ $\sigma = 0.98$				-0.03	1.33	0.9
	$\langle = 4.17^{56}$ $\sigma = 0.89$	$\langle = 4.79^{55}$ $\sigma = 0.42$	$\langle = 4.2$ $\sigma = 0.8$	$\langle = 4.58$ $\sigma = 0.67$	0.03	0.77	0.83	-0.21	0.74	0.11

- Perception of the inquiry process in general. Both in the intermediate stage and in the final stage of the inquiry, the students agree (values between 4 and 4.5) that learning through inquiry is the student's independent and active learning, which enables the student to be involved in learning and to build his knowledge.

⁵⁰ Statement: Learning through inquiry is the independent and active learning of the student, which enables the student to be involved in the learning and to build his knowledge by himself.

⁵¹ Statement: In the performance of the inquiry activities many opportunities were given to participate actively in the learning process and to build the knowledge by yourself.

⁵² Statement: In the performance of the inquiry activity I experienced independent and active learning, in which I was active fully in the learning, doing, and thinking.

⁵³ Statement: In the performance of the inquiry activity I experienced independent and active learning, in which I was active fully in the learning, doing, and thinking.

⁵⁴ Statement: The program contributed to the development or improvement in the issue: the ability of active learning and independent learning, through which the student builds the knowledge and understanding of the content relevant to the inquiry.

⁵⁵ Statement: The program contributed to the development of improvement the issue: the ability of active learning and independent learning, through which the student builds the knowledge and understanding of the content relevant to the inquiry.

⁵⁶ Statement: Performance of the inquiry activities strengthened my knowledge in the scientific content (in physics particularly), performance of inquiry activity promoted in me in-depth understanding of physical concepts and principles.

- Perception of the learning environment in actuality. Both in the intermediate stage and in the final stage of the inquiry, the students agree (values between 4 and 5) that many opportunities are given to participate actively in the learning process and to build the knowledge themselves and that they experienced independent learning and active learning in the performance of inquiry activities in the program. In addition, it is possible to see that both in the intermediate stage and in the final stage towards the end of the year the degree of agreement of this experience has increased (above the value of 4.5).
- Perception of the contribution of the learning environment. Both in the intermediate stage and in the final stage of the inquiry, the students agree (value between 4 and 4.5) that the program contributed to the development / improvement on the issue: ability of active learning and independent learning through which the student builds the knowledge and his understanding of the content relevant to the inquiry. In addition, the students strengthened their knowledge in the scientific content (in physics in particular) and promoted in them in-depth understanding of physical concepts and principles. Moreover, both in the intermediate stage and in the final stage of the inquiry, the students agree greatly (value between 4.5 and 5) that they broadened their knowledge to physical topics that are beyond the curriculum in the school.
- Comparison of perceptions between in general and in actuality. Both in the intermediate stage and in the final stage of the inquiry, the students' perception of the building of the content knowledge in the inquiry work after the experience in actuality was commensurate with their perception from the beginning. This is commensurate with their view of the contribution of the experience to the improvement of their ability to build knowledge.

4.2.2.2 *Qualitative Analysis from the Interviews*

From the interviews, that were held after the submission of the intermediate report at the end of the 11th grade, it is possible to see the students' perception in the issue of building content knowledge, in the context of independent learning, active learning, knowledge based on practical experience or during experience, and what is the level of understanding of the theoretical material relevant to the inquiry and including their ability

to build knowledge (Appendix 4.2.5 presents examples of student quotes from the interviews), primarily from the following questions:

1. What in your opinion is the uniqueness of the research physics program?
2. What challenges did you have in the inquiry work and how did you cope with them?
3. How did you learn the theoretical material relevant to your inquiry? Was there independent learning?
4. Did you improve the ability to learn by yourself? If so, describe
5. Do you understand the theoretical material relevant to your inquiry? Do you feel you have mastered the material?
6. What did you learn about yourself from the program?
7. What did you learn from the program? Or what did the program contribute to you?

One of the things that were prominent in the interviews is that the students see that the uniqueness of the Research Physics program is the way in which they build the content knowledge. First, the students note that for the most part they themselves build the knowledge and not the teacher of the school and considerable active learning and independent learning are required of them. The students describe the actions that they did to build the knowledge, such as the search for information sources relevant to the material, organization of the new material, giving explanations to the phenomenon, discovery/finding the formula (algebraic expression) that describes the dependence of the variables, and the use and implementation of the knowledge acquired for the continuation of the investigation.

Second, most of the students who were interviewed tell that the building of the knowledge and learning of the theory was during the practical experience (performance of the experiment) or afterwards. The students note the fact that they found the dependence between the variables in the experiment and even found from this the mathematical expression that describes this dependence caused them to understand in greater depth the phenomenon and the theoretical material relevant to the phenomenon. Only two students (examples A, G in appendix 4.2.5) noted that the learning of the theory was before the performance of the experiments and only in the first part of the inquiry. Nevertheless, also in this stage the experiment caused them to understand the theory better.

In addition, the students report that they learned about themselves that they can learn theoretical material unfamiliar to them and to understand in-depth the behavior of the researched phenomenon independently or semi-independently. In addition, the students noted that they developed the ability to learn independently during the inquiry work. Some of the students mentioned that the experience of independent learning was new for them (for example, D and E in appendix 4.2.5), and some noted that they had this ability even before the inquiry work in the program, since this inquiry work required of them considerable experience of independent learning they strengthened this ability (for example, examples H and I in appendix 4.2.5).

Alongside the independent learning and the active learning in the inquiry work, it is possible to see from the quotes that occurred also in the cooperative learning with the partner and with the teacher-mentor when they did not succeed in building the knowledge by themselves. According to the students, the teacher-mentor needs to encourage the student to learn independently, to enable the student's coping with the challenges innate in this learning, and to give the time to overcome it through support and direction as needed. According to the students, the teacher-mentor's role is to provide an answer to questions that they could not solve on their own but not only by giving explanations but also by directing and encouraging the search for other sources and additional solutions that will help them find the answer to their question. In addition, according to the students the teacher-mentor needs to stimulate and inspire the curiosity of the students to additional things that are relevant to their inquiry, concurrently to focus the students and to simplify the more complex material for them, or in other words, to promote them in the research and to develop the ability of their independent learning.

The main aspects that arise from the students' statements on the topic of the building of knowledge in the inquiry work are as follows (Appendix 4.2.5 presents examples illustrating these aspects):

A. The participants' roles:

1. The building of knowledge in the inquiry obligates the student to learn actively, responsibly, and with initiative (the students need to search for sources of relevant information, to organize the knowledge, to discover the relationship between the participants in the experiment, to understand the meaning of the

formula, to explain the phenomenon, and to use the knowledge acquired for the continuation of the investigation).

2. The building of the knowledge in the inquiry obligates considerable independent learning alongside cooperative learning with the partner and with the accompanying teacher-mentor.
- B. Reciprocal relationships between experiment and theory: In the building of the knowledge in the inquiry, for the most part the experiment can come before or in parallel to the theoretical explanations.
- C. Products:
1. Building knowledge in inquiry produces in-depth understanding of behavior of the researched phenomenon and theory that explains it.
 2. Experience in the building of knowledge in inquiry increases the student's feeling of self-efficacy in the learning of new theoretical material for him and in his ability to learn this independently (since the teacher-mentor gives time for this and does not immediately bring explanations/responses).

4.2.3 The Students' Perception of the Aspect: Teamwork in the Inquiry Work (in Stage 2 and Stage 3 of the Inquiry Work)

4.2.3.1 Teamwork with the Partner in the Inquiry Project in General and the Actual Learning Environment according to the Students (in Stage 2 and Stage 3 of the Inquiry Work)

This subchapter presents the quantitative findings of the self-reporting questionnaires distributed at four points of time. Time points (N=33): Middle of eleventh grade: February 2018/ End of eleventh grade: April 2018/ Middle of twelfth grade: January 2019/ End of twelfth grade: May 2019. The students (N=33) were asked to address the student's role in the aspect of teamwork with the peer in the inquiry project, from two viewpoints: in general– how do they perceive the inquiry process generally in this aspect, and in actuality – how do they perceive the actual learning environment and the contribution of this environment.

In this section, the questions are Likert scale (from Attitudes Questionnaire & Summative Questionnaire, see in Appendices 1.3, 1.4), in which the student is asked to indicate the degree to which he agrees with different statements on a scale of 1-5 (1 – not at all, 5 – greatly).

The following table presents the findings (reader: $\langle \rangle$ =mean, σ = standard deviation):

Table 22: The Students' Perception of the Teamwork with the Project Partner in General and the Actual Learning Environment (N=33)

Time Point	Intermediate Stage of the Inquiry Work		Final Stage of the Inquiry Work		$\Delta \langle \rangle$	$\Delta \sigma$	Pr > t	$\Delta \langle \rangle$	$\Delta \sigma$	Pr > t
	Middle 11 th February 2018	End 11 th April 2018	Middle 12 th January 2019	End 12 th May 2019						
Source of information: Questionnaire	Attitudes	Summative	Attitudes (Repeat)	Summative (Repeat)	Attitudes			Summative		
Perception of the inquiry process in general	$\langle \rangle = 3.97^{57}$ $\sigma = 1.03$		$\langle \rangle = 4.27$ $\sigma = 0.94$		0.3	1.47	0.27			
Perception of the learning environment in actuality	$\langle \rangle = 4.18^{58}$ $\sigma = 0.98$		$\langle \rangle = 4.33$ $\sigma = 0.96$		0.15	1.12	0.44			
Perception of the contribution of the learning environment	$\langle \rangle = 4.09^{60}$ $\sigma = 0.77$	$\langle \rangle = 4.35^{59}$ $\sigma = 0.75$	$\langle \rangle = 4.36$ $\sigma = 0.74$	$\langle \rangle = 4.14$ $\sigma = 0.95$	0.27	1.01	0.13	-0.21	1.08	0.27

- Perception of the inquiry process in general. Both in the intermediate stage and in the final stage of the inquiry, the students agree (values between 4 and 4.5) that the research carried out in pairs/small group is more productive than a research performed by a single researcher.

⁵⁷ Statement: Research performed in pairs/small group is more productive than a research performed by a single researcher

⁵⁸ Statement: The performance of inquiry activity performed in pairs enabled experience in peer learning and experience in teamwork and there was complete cooperation in the activity and learning between the group members.

⁵⁹ Statement: The program contributed to the development or improvement in the issue of cooperation in teamwork, cooperative learning with the partner.

⁶⁰ Statement: Performance of inquiry activities developed in me abilities of teamwork and learning from peers (such as cooperation, listening, openness to accept others' opinions, to share deliberations with others, to brainstorm, to express myself in the team, to hold a respectful discussion).

- Perception of the learning environment in actuality. Both in the intermediate stage and in the final stage of the inquiry, the students agree (values between 4 and 4.5) that in the performance of inquiry activities in the program they experienced teamwork that necessitated full cooperation in the doing and learning between the group members.
- Perception of the contribution of the learning environment. Both in the intermediate stage and in the final stage of the inquiry, the students agree (values between 4 and 4.5) that the performance of inquiry in the program developed in them abilities of teamwork and learning from peers (such as cooperation, listening, openness to another's opinion, sharing with others the deliberations, brainstorming, expressing the self in the team, and holding a respectful discussion.)
- Comparison of perceptions between in general and in actuality. Both in the intermediate stage and in the final stage of the inquiry, the students' perception of the teamwork with the project partner in the inquiry work after the experience in actuality was commensurate with their perception from the beginning and this is commensurate with their view of the contribution of the experience to the improvement of the practices of teamwork and cooperative learning with peers.

4.2.3.2 *Qualitative Analysis from the Interviews*

From the interviews, that were held after the submission of the intermediate report at the end of the 11th grade, it is possible to see the students' perception of cooperative learning and teamwork with the partner in the inquiry project (Appendix 4.2.6 presents examples of student quotes from the interviews), primarily from the following questions:

1. Tell me about the teamwork between you and your partner in the inquiry project.
2. Was there a division of roles between you? If so, describe.
3. In your opinion, what is preferable, to perform inquiry work in a pair or s alone?
4. What did you learn about yourself from the teamwork with the partner?
5. What did you learn in social terms from the program?

Primarily from the last two questions, it can be seen in the students' quotes that shown in Appendix 4.2.6, the students' perception on the issue of cooperative learning and teamwork: first, all the students who were interviewed prefer to work with the partner and

not alone in the inquiry work because of its advantages. Moreover, in the two examples, (example B and example F in Appendix 4.2.6), it is possible to see that the students have changed their perception. At first they thought that inquiry work should be performed alone, and during the program they understood that it is preferable with a partner and even understood that this is essential to the inquiry work.

In addition, the students learned from the teamwork about themselves that they can work in a team (which is not self-evident), that they can be patient with and attentive to their partner, to make compromises when needed, to convey criticism in a dignified manner and to accept criticism, and that they can rely on somebody else. In general, it is possible to see that the students perceive the cooperative learning and teamwork as vital practices in the inquiry work and in general.

The main aspects that arise from the students' statements on the topic of the advantages of teamwork in inquiry work are as follows (Appendix 4.2.6 presents examples illustrating these aspects):

- A. Clarification of principles, concepts, and ideas in conversation
 - 1. Mutual fertilization in the understanding of the theory and ways of inquiry.
 - 2. Brainstorming for solving problems, developing ideas, and directions of inquiry.
- B. Division of roles
 - 1. Division of the work to make the inquiry more effective and to advance it.
 - 2. Complement of one another – each one contributed to the performance of the project of the part that he is better in.
- C. Interpersonal abilities
 - 1. Willingness to compromise (patience, listening, receiving criticism, mutual respect, and ability of inclusion).
 - 2. Confidence in the project partner as somebody who can be relied on.
 - 3. Commitment to the project partner to perform his part in the project.
 - 4. Support and reinforcement of the partner (especially in situations of frustration).
 - 5. Enjoyment of the activity together and the relations of friendship created.

4.2.3.3 *Teamwork with the Peers in the Broader Group in the Inquiry Project in General and the Actual Learning Environment according to the Students (in Stage 2 and Stage 3 of the Inquiry Work)*

This subchapter presents the quantitative findings of the self-reporting questionnaires that were distributed at four points of time. Time points: Middle of eleventh grade: February 2018/ End of eleventh grade: April 2018/ Middle of twelfth grade: January 2019/ End of twelfth grade: May 2019. The students (N=33) were asked to address the student’s role in the aspect of the evaluation of the peers of the broader group in the inquiry work, from two perspectives: in general– how do they perceive the inquiry process generally in this aspect, and in actuality – how do they perceive the actual learning environment and the contribution of this environment. In this section, the questions are Likert scale (from Attitudes Questionnaire & Summative Questionnaire, see in Appendices 1.3, 1.4), a scale of 1-5 (1 – not at all agree, 5 – greatly). The following table presents the findings (reader: $\langle \rangle$ =mean, σ = standard deviation):

Table 23: The Students’ Perception of the Teamwork with the Peers in the Broader Group in an Inquiry Work in General and the Actual Learning Environment (N=33)

Time Point	Intermediate Stage of the Inquiry Work		Final Stage of the Inquiry Work		$\Delta \langle \rangle$	$\Delta \sigma$	Pr > t	$\Delta \langle \rangle$	$\Delta \sigma$	Pr > t
	Middle 11 th February 2018	End 11 th April 2018	Middle 12 th January 2019	End 12 th May 2019						
Source of information: Questionnaire	Attitudes	Summative	Attitudes (Repeat)	Summative (Repeat)	Attitudes			Summative		
Perception of the inquiry process in general	$\langle \rangle = 3.66^{61}$ $\sigma = 1.00$		$\langle \rangle = 3.50$ $\sigma = 1.19$		-0.16	1.19	0.46			
Perception of the learning environment in actuality	$\langle \rangle = 3.36^{62}$ $\sigma = 1.08$		$\langle \rangle = 3.44$ $\sigma = 1.09$		0.08	1.42	0.47			
Perception of the contribution of the learning environment		$\langle \rangle = 3.97^{63}$ $\sigma = 0.85$		$\langle \rangle = 3.49$ $\sigma = 1.15$				-0.48	1.2	0.027

⁶¹ Statement: The evaluation of peers (evaluation of the members of the class/broader group) is an inseparable part of the scientific inquiry process.

⁶² Statement: In the performance of the inquiry activities time was dedicated to the evaluation of the peers (evaluation done by the members of the class/broader group)

⁶³ Statement: The program contributed to the development or improvement on the issue: ability to perform peer evaluation in the broader group.

- Perception of the inquiry process in general. Both in the intermediate stage and in the final stage of the inquiry, the students agree to a certain degree but not fully (values between 3.5 and 4) that the peer assessment in the broader group is an inseparable part of the process of scientific inquiry.
- Perception of the learning environment in actuality. The students agree to a certain extent but not fully (values between 3 and 3.5) that time was dedicated to the evaluation of the peers in the broader group in the performance of the inquiry activities in the program.
- Perception of the contribution of the learning environment. Both in the intermediate stage and in the final stage of the inquiry, the students agree to a certain degree (values between 3.5 and 4) that the experiences in the inquiry activities in the program contributed to the development/improvement of the ability of peer evaluation. But there is a significant decline in this perception (statement 63) between the intermediate stage and the final stage of the inquiry work
- Comparison of perceptions between in general and in actuality. Both in the intermediate stage and in the final stage of the inquiry, the students' perception of the evaluation of the peers in the broader group after the experience in actuality was less than their perception from the beginning and the students also do not see with full agreement (values between 3.5 and 4, the values are not high relative to the attitudes in the other aspects) the contribution of the experience to the improvement of their performance ability in the peer assessment.

4.2.3.4 *Qualitative Analysis from the Interviews*

From the interviews, that were held after the submission of the intermediate report at the end of the 11th grade, it is possible to see the students' perception of work in the team with the peers in the broader group in the inquiry work (Appendix 4.2.7 presents examples of student quotes from the interviews), primarily in the questions:

1. Was there the evaluation of peers in the broader group? Tell how this was in actuality. What do you think about this instrument?
2. Was there peer learning in the broader group?

3. How was your relationship with the participants in the broader group in general?
Did the relationship you created in the inquiry work help you / were you helped by one another?
4. What is the contribution of the program in social terms?

It is possible to see that the students who were interviewed are aware of the importance of the evaluation from the peers of the broader group and of giving mutual help to the other members of the team. But some of them note that not enough activities have been done that include the evaluation of peers during the inquiry work and infrequently mutual assistance occurred between the other teams. One of the explanations according to the students is that it is reasonable to assume that every research team engaged in a different field of inquiry (so that they could not help another team that engaged in a different knowledge field). In addition, the students are very busy and are focused on their inquiry work, so that they were not free to help others. However, the students recommend creating more social interactions and especially to hold more activity of the evaluation of peers during the inquiry work.

The main aspects that arise from the students' statements on the issue of teamwork with peers in the broader group are as follows (Appendix 4.2.7 presents examples illustrating these aspects):

1. Evaluation of peers focuses the students with the help of giving recommendations to improve the practical work, the written work and its presentation.
2. The evaluation of peers provides the students with proposals for the continuation of the investigation.
3. The evaluation of peers provides satisfaction and confidence to students for their work and their presentation.
4. The evaluation of peers exposes the students to other researches.
5. The evaluation of peers reduces the fear of accepting criticism, because it comes from their peers – at their level.
6. The mutual help of the peers in the broader group contributes to the progress of the students in the inquiry work.
7. The mutual help of the broad group gives a relaxed learning atmosphere, which is good and fun.

4.2.4 The Students' Perception of the Aspect: Identifying with the World of the Scientific Researcher (in Stage 2 and Stage 3 of the Inquiry Work)

4.2.4.1 Identifying with the World of the Scientific Researcher in General and the Actual Learning Environment according to the Students (in Stage 2 and Stage 3 of the Inquiry Work)

This subchapter presents the quantitative findings of the self-reporting questionnaires distributed in four time points. Time points: Middle of eleventh grade: February 2018/ End of eleventh grade: April 2018/ Middle of twelfth grade: January 2019/ End of twelfth grade: May 2019.

The students (N=33) were asked to address the aspect of the student's identification with the world of the scientific research. The questionnaires presented general statements that express the identification with the world of the scientist/researcher, in the context of the environment in which the students hold the inquiry and the learning resources at their disposal (research conditions), in addition, in the context of the understanding of the inquiry process like a researcher/scientist, in the context of the discovery of curiosity in the performance of the inquiry project, and in the context of self-efficacy to be a researcher in the future, from two viewpoints: in general– how do they perceive the inquiry process generally in this aspect, and in actuality – how do they perceive the actual learning environment and the contribution of this environment.

In this section, the questions are Likert scale (from Attitudes Questionnaire & Summative Questionnaire, see in Appendices 1.3, 1.4), in which the student is asked to indicate the degree to which he agrees with different statements on a scale of 1-5 (1 – not at all, 5 – greatly).

The following table presents the findings (reader: $\langle \rangle$ =mean, σ = standard deviation):

Table 24: The Students' Perception: Identifying with the World of Scientific Research
in General and the Actual Learning Environment according to Students (N=33)

Time Point	Intermediate Stage of the Inquiry Work		Final Stage of the Inquiry Work		$\Delta\langle$	$\Delta\sigma$	Pr > t	$\Delta\langle$	$\Delta\sigma$	Pr > t
	Middle 11 th February 2018	End 11 th April 2018	Middle 12 th January 2019	End 12 th May 2019						
Questionnaire	Attitudes	Summative	Attitudes (Repeat)	Summative (Repeat)	Attitudes			Summative		
Perception of the inquiry process in general	$\langle = 4.23^{64}$ $\sigma = 0.73$		$\langle = 4.33$ $\sigma = 0.65$		0.1	0.68	0.38			
Perception of the learning environment in actuality		$\langle = 4.49^{65}$ $\sigma = 0.43$		$\langle = 4.40$ $\sigma = 0.63$				-0.09	0.67	0.46
Perception of the contribution of the learning environment	$\langle = 4.18^{67}$ $\sigma = 0.69$	$\langle = 4.76^{66}$ $\sigma = 0.44$	$\langle = 4.24$ $\sigma = 0.65$	$\langle = 4.55$ $\sigma = 0.66$	0.06	0.65	0.59	-0.21	0.82	0.15
		$\langle = 4.71^{68}$ $\sigma = 0.56$		$\langle = 4$ $\sigma = 1.08$				-0.71	0.93	0.0001
		$\langle = 4.26^{69}$ $\sigma = 0.6$		$\langle = 4.16$ $\sigma = 0.61$				-0.1	0.7	0.37

- Perception of the inquiry process in general. Both in the intermediate stage and in the final stage of the inquiry, the students agree (values between 4 and 4.5) that the inquiry activities need to exist in the conditions of research for students (such as laboratory and sophisticated equipment, accompaniment of experts, teacher-mentors, laboratory technicians, and scientists) and that inquiry activities enable familiarity with the world of the scientific researcher.

⁶⁴ Statements: Inquiry activities need to exist under conditions of research for the students (such as laboratory and sophisticated equipment, accompaniment of experts, teacher-mentors, laboratory assistance, and scientists), inquiry activities enable familiarity with the world of the scientific researcher.

⁶⁵ Statements: I felt that I perform the work of a scientist-researcher, ways of the thinking in the project and in physics in the school are similar (opposite statement), I felt that this is a school project, not scientific work (opposite statement), and the project was interesting and challenging, the project does not challenge me (opposite statement).

⁶⁶ The program contributed to the development or improvement in the issue of knowledge and understanding about the inquiry process, the development of inquiry skills as required of the researcher.

⁶⁷ Statements: Performance of inquiry activities strengthened my knowledge and understanding of inquiry in general, performance of inquiry activities improved my inquiry skills, performance of inquiry activities cultivated general and practical skills and practices in the field of scientific inquiry.

⁶⁸ Statements: I am interested in coping in the future with a research project, I am not interested in coping in the future with research projects (opposite statement).

⁶⁹ Statements: The program contributed to the development or improvement on the issue, curiosity for the studies of science and investigation of physical phenomena in particular, like the researcher's scientific curiosity.

- Perception of the learning environment in actuality. Both in the intermediate stage and in the final stage of the inquiry, the students agree greatly (values close to 4.5) that the inquiry project was interesting and challenging and that they felt that they are performing the work of the scientist-researcher in the Research Physics program.
- Perception of the contribution of the learning environment. Both in the intermediate stage and in the final stage of the inquiry, the students agree (values between 4 and 5) that the experiences in the inquiry activity in the program strengthened the knowledge and understanding about the inquiry process itself and cultivated general and practical practices and skills of inquiry in the field of scientific inquiry, like the scientist does. In addition, at the end of each year, the degree of agreement on this contribution increased above the value of 4.5. Moreover, most of the students agree (values between 4 and 5) that the program contributed to the development of curiosity for the studies of science and investigation of physical phenomena like the researcher's scientific curiosity and that they are interested in coping in the future with the research project. However, there is a significant decline from the intermediate stage (the end of the eleventh grade) to the final stage (end of the 12th grade) on the issue of the desire to cope in the future with the inquiry project, but still the degree of agreement is high (value 4) in the final stage.
- Comparison of perceptions between in general and in actuality. both in the intermediate stage and in the final stage of the inquiry, the students' perception of the world of the scientific researcher after the experience in actuality was commensurate with their perception from the beginning. This is commensurate with their view of the contribution of the experience to the improvement of their knowledge and understanding about the inquiry process itself and the cultivation of inquiry skills and practices required for the scientific researcher.

4.2.4.2 *Qualitative Analysis from the Interviews*

From the interviews, that were held after the submission of the intermediate report at the end of the 11th grade, it is possible to see the students' perception of the scientific researcher's world, in an environment in which the students perform the inquiry (Appendix 4.2.8 presents examples of student quotes from the interviews), primarily in the questions:

1. In your opinion, what is the uniqueness of the research physics program?
2. Are you satisfied with the product? What do you think about your performances in the program?
3. With what are you satisfied in the program?
4. What did you learn from the program about yourself?
5. Did the program give you the motivation to learn physics in the future or to learn research, to engage in inquiry in the future?

It is possible to see that the students describe the uniqueness of the research physics program as an environment similar to the laboratory environment of the scientific researcher. The main reasons the students identify with the world of the scientific research (in the environment in which they researched the phenomenon) are as follows (Appendix 4.2.8 presents examples illustrating these aspects):

1. They have at their disposal learning resources: diverse and sophisticated equipment for the performance of experiments and processing of the data, close instruction of the experts, time to perform a full and in-depth inquiry – a long-term research.
2. Style of experiment: More complex experiments than in the school (both because of the requirement for the improvement of the system for accuracy of measurements and because of the depth of the inquiry), high level of data processing, results of the experiment are not known ahead of time, and the student needs to discover the results by himself and to plan the ways of investigation.
3. Feeling of experience of the researcher, which includes understanding of the nature of the inquiry process. Following this experience, some of the students expressed interest in engaging in research in the future.

4.3 The Students' Degree of Satisfaction with the Instruction of the Teacher-Mentor in the Research Physics Program

This chapter describes the degree of satisfaction of the students with the instruction they received in the “Research Physics” program and the causes of this, from the students’ answers (Appendix 4.3 presents examples of the students’ quotes) from the summative questionnaire (see Appendix 1.4). The questionnaire was held at two times, towards the end of the intermediate stage of the inquiry work in the eleventh grade (April 30, 2018, N=33), towards the end of the final stage of the inquiry work in the twelfth grade (May 2019, N=34). At the end of the chapter, a summary is presented of the main aspects in the students’ satisfaction with their project teacher-mentor’s instruction, from which it is possible to understand how the students perceive the teacher-mentor’s role in an environment focused on the inquiry project.

4.3.1 Stage 2 – Intermediate Stage of the Inquiry Project – Students’ Degree of Satisfaction with the Instruction (Self-Reporting Questionnaire before the Submission of the Intermediate Report, 11th Grade)

4.3.1.1 Quantitative Analysis – The Students’ Degree of Satisfaction with the Instruction in the Intermediate Stage (Stag 2 – 11th Grade)

The following is the quantitative analysis of the students’ reports on the students’ degree of satisfaction with their teacher-mentor’s instruction in the intermediate stage of the inquiry work, from the summative questionnaire (see Appendix 1.4). The questionnaire was held before the submission of the project intermediate report in the second half of the eleventh grade, after the students’ presentation on the project (April 30, 2018, N=33), when there is a teacher-mentor close to every research team. The students were asked to note their degree of satisfaction regarding different statements that appear in the following table, according to ranked scale of 1-4 (when 1 – not satisfied, 2 – slightly satisfied, 3 – satisfied, 4 – very satisfied). The values written in the last four columns note the percentage of the frequency in number 1-4.

Table 25: Degree of the Students' Satisfaction with the Teacher-Mentor's Instruction
(11th Grade)

Statement	N	Mean	Std	1	2	3	4
Instruction in the choice of the topic and planning of the project	33	3.36	0.78	3.03	9.09	36.36	51.52
Responsiveness to questions during the work	33	3.49	0.76	3.03	6.06	30.30	60.61
The physical knowledge of the instruction staff	33	3.64	0.7	3.03	3.03	21.21	72.73
Instruction for presentation before peers	33	3.06	1.06	12.12	15.15	27.27	45.45
Teacher-mentor's support in teamwork	33	3.36	0.93	6.06	12.12	21.21	60.61
All these statements	33	3.38	0.71	3.03	6.06	36.36	54.55

- It is possible to see from the table above, the last row, that in the intermediate stage of the inquiry work (eleventh grade) most of the students report that they are satisfied with the teacher-mentor's instruction (55% very satisfied and 36% satisfied, a total of 91%) and about one-tenth of the students are not satisfied enough with the teacher-mentor's instruction (3% are not satisfied and 6% are a little satisfied, a total of 9%). The mean is 3.38, when 4 is the maximal value.
- We look at the mean of every statement of the students' satisfaction and obtain the order of the statements from the high to the low mean: The physical knowledge of the instruction staff, responsiveness to questions during the work, the teacher-mentor's support of the teamwork, and instruction in the choice of the topic and the planning of the project, and instruction for the presentation before the peers.
- We go in-depth into the percentages of frequency, especially in numbers 3 (satisfied), 4 (very satisfied) from the scale of 1-4, we obtain, respectively, more students satisfied with the physical knowledge of the instruction staff, the teacher-mentors' responsiveness to the students' questions (more than 90% are satisfied to very satisfied). In addition, many students are satisfied with the instruction in the choice of the topic and planning of the project and the teacher-mentor's support of the teamwork (more than 80% of the students are satisfied to very satisfied).

Relative to the other statements, the least number of students are satisfied with the instruction they received before the presentation to the peers (about 72% are satisfied to very satisfied).

4.3.1.2 Qualitative Analysis – The Students’ Degree of Satisfaction with the Teacher-Mentor’s Instruction in the Intermediate Stage (Stag 2 – 11th Grade)

This section presents a qualitative analysis of the students’ reports on their satisfaction with the teacher-mentor’s instruction in the intermediate stage (eleventh grade, N=33) of the inquiry work in the Research Physics program. (from the summative questionnaire, see Appendix 1.4). The students describe the reasons for their satisfaction or lack of satisfaction with the instruction. The students’ responses arose from the questions: Note two-three strengths of the program that it is important to keep, regarding your satisfaction with the cooperation between students and teacher-mentors, if you are not satisfied please describe what bothered you (Appendix 4.3.1 is shown examples of student citations).

4.3.1.2.1 Satisfaction of the Students with the Teacher-Mentor’s Instruction in the Intermediate Stage (11th Grade)

As noted in the quantitative analysis, most of the students in this stage report that they are satisfied with their teacher-mentor’s instruction (91%). These students describe the causes of their satisfaction with the instruction they received in the framework of the program.

Causes of the Students’ Satisfaction with the Teacher-Mentor’s Instruction are as follows (Appendix 4.3.1 presents examples of student quotes indicate these reasons):

1. Giving a certain free space in the choice of the direction of investigation and the way of investigation, which enables the students to learn and to research independently, to take responsibility for their inquiry work, and to initiate the advance of the investigation.
2. Availability and responsiveness of the teacher-mentors for the questions, giving feedback on their work, and on giving help to build the knowledge.
3. Professional accompaniment of all the instruction staff that includes the other teacher-mentors (not only the personal teacher-mentors), academic counselors, and laboratory technicians.

4. Different preparation activity undertaken in the first year (in the tenth grade) with the help of the teacher-mentors to acquire inquiry practices and to obtain tools for the continuation of the inquiry work in the program.

4.3.1.2.2 Lack of Satisfaction of the Students with the Teacher-Mentor's Instruction in the Intermediate Stage (11th Grade)

As noted in the quantitative analysis, about one-tenth of the students (9%) are not sufficiently satisfied with the teacher-mentor's instruction in the intermediate stage (eleventh grade, N=33) of the inquiry work. These students wrote different reasons for the lack of satisfaction with the instruction that they received in the program framework (Appendix 4.3.1 is shown examples of student citations). We note that these reasons do not speak about all the teacher-mentors and sometimes a number of arguments are linked to one teacher-mentor.

Causes of the students' lack of satisfaction with the teacher-mentor's instruction are as follows (Appendix 4.3.1 presents examples of student quotes indicate these reasons):

1. The lack of direction in learning and investigation, despite the students' awareness of the importance in independent learning as an inseparable part of the inquiry process.
2. Little freedom of expression and action for the students in the inquiry process.
3. Lack of knowledge of the teacher-mentor and required skills in order to advance the inquiry work.
4. Commitment of the teacher-mentor to come in an orderly manner to the meetings of the program and to give them support in the inquiry work.

The students describe suggestions / ways of coping

1. To give more direction on the part of the teacher-mentors (alongside the independent learning) in the focusing of the theoretical material relevant to the inquiry and in the building of knowledge and understanding of the researched phenomenon (such as giving more information sources relevant to their inquiry, giving a preliminary explanation to the concepts, principles, ways of analysis of complicated data).
2. To give more freedom of thought and action to the student.
3. To suit the teacher-mentors to the students and if it is necessary to change the teacher-mentors so that they will suit the students.

4.3.2 Stage 3 – Final Stage of the Inquiry Project – Students’ Degree of Satisfaction with the Instruction (Self-Reporting Questionnaire before the Submission of the Summative Report, 12th Grade)

4.3.2.1 Quantitative Analysis – The Students’ Degree of Satisfaction with the Teacher-Mentor’s Instruction in the Final Stage (Stage 3 – 12th Grade)

This section presents the quantitative analysis of the students’ reports of their satisfaction with their teacher-mentor’s instruction from the summative questionnaire (see Appendix 1.4). The questionnaire was held before the submission of the project summative report, in the second half of the twelfth grade, after the students’ presentation on the project (May 2019, N=34). The students were asked to note their degree of satisfaction regarding different statements that appears in the following table, according to a ranked scale of 1-4 (when 1 – not satisfied, 2 – slightly satisfied, 3 – satisfied, 4 – very satisfied). The values written in the last four columns note the percentage of frequency in numbers 1-4.

Table 26: Degree of the Students Satisfaction with the Teacher-Mentor’s Instruction (12th Grade)

Statement	N	Mean	Std	1	2	3	4
Instruction in the choice of the topic and planning of the project	34	3.09	0.9	2.94	26.47	29.41	41.18
Responsiveness to questions during the work	34	3.29	0.84	5.88	5.88	41.18	47.06
The physical knowledge of the instruction team	34	3.35	0.88	2.94	17.65	20.59	58.82
Instruction for the presentation before the peers	34	3.03	1.03	8.82	23.53	23.53	44.12
The teacher-mentor’s support of the teamwork	34	3.26	0.96	8.82	8.82	29.41	52.94
All these statements	34	3.22	0.74	2.94	11.76	44.12	41.18

- It is possible to see from the above table, the bottom row, that in the final stage of the inquiry work (twelfth grade) most of the students report that they are satisfied with their teacher-mentors’ instruction (41% are very satisfied and 44% are satisfied, for a total of 85%) and a little less than one-sixth of the students are not

sufficiently satisfied by the teacher-mentor's instruction (3% are not satisfied and 12% are slightly satisfied, a total of 15%). In the comparison to the previous stage (see 3.1.1), there is a decline of 5% of the students' satisfaction from the intermediate stage to the final stage of the inquiry work.

- If we look at the mean of each statement in the students' satisfaction and obtain the mean order of the statements from high to low: the physical knowledge of the instruction staff, the responsiveness to the questions during the work, the teacher-mentor's support of the teamwork, and the instruction in the choice of the topic and planning the project, instruction for presentation before the peers. We note that this is the same order we obtained in the previous stage, the intermediate stage of the inquiry work.
- If we go in-depth into the percentages of frequency, especially in numbers 3, 4 in the scale of 1-4. It is possible to see that in this stage, the final stage of the inquiry work, more students are satisfied with the teacher-mentors' support of the teamwork (about 87% are satisfied to very satisfied). In addition, many students are satisfied with the physical knowledge of the instruction staff, the teacher-mentors' responsiveness to the students' questions (about 80% are satisfied to very satisfied). Relative to the other statements, fewer students are satisfied with the instruction they received in the choice of topic and planning of the project (about 70% are satisfied to very satisfied) and the least number of students are satisfied with the instruction before the presentation in front of the peers (about 67% are satisfied to very satisfied).
- In the comparison to the quantitative analysis in the previous stage, the intermediate stage (see 3.1.1.) a significant change ($p>.05$) was not found between the means of the final stage and the intermediate stage of the inquiry work (the mean of all the statements, eleventh grade: 3.38, twelfth grade 3.22, $N=33$). Nevertheless, it is possible to see the trend of decline in the students' satisfaction with the instruction staff in the mean from the final stage as opposed to the mean of the intermediate stage mainly in the statements: instruction in the choice of the topic and planning the project (mean of the final stage: 3.36, intermediate stage: 3.09), responsiveness to the questions during the work (mean final stage 3.49 versus 3.29), the physical knowledge of the instruction staff (mean of final stage: 3.64 versus mean of intermediate stage: 3.35).

4.3.2.2 Qualitative Analysis – Description of the Students’ Degree of Satisfaction with the Teacher-Mentor’s Instruction in the Final Stage (Stage 3 – 12th Grade)

This section presents a qualitative analysis of the students’ reports on their satisfaction with their teacher-mentor’s instruction in the final stage (twelfth grade, N=34) of the inquiry work in the Research Physics Program (from the summative questionnaire, see Appendix 1.4). The students described the reasons for their satisfaction and the reasons for their lack of satisfaction with the instruction. The students’ responses arose from the questions: "Note two-three strengths of the program that it is important to keep, if you are not satisfied with teacher-mentor’s instruction please describe what bothered you" (Appendix 4.3.2 is shown examples of student citations).

4.3.2.2.1 The Students’ Satisfaction with the Instruction in the Final Stage (12th Grade)

As noted in the quantitative analysis, most of the students in this stage report that they are satisfied with their teacher-mentor’s instruction (85%). These students describe the factors of their satisfaction with the instruction they obtained in the framework of the program.

The Factors of the Students’ Satisfaction with the Teacher-Mentor’s Instruction are as follows (Appendix 4.3.2 presents examples of student quotes indicate these reasons):

1. The teacher-mentor’s degree of involvement, the increase of the freedom of action and independence for the student in the management and leading of the inquiry, alongside giving support and direction as needed.
2. The teacher-mentors’ experience and considerable knowledge both in the content of the researched topic and in making the content accessible and in the guidance of the inquiry.
3. Cooperation and mutual coordination between the teacher-mentor and the student for the requirements and the expectations.
4. Providing a personal reference and display of empathy to the students and full commitment and focus of the teacher-mentors on their project.
5. The openness and trust created between the teacher-mentors and the students enable the students to feel comfortable asking for support both in the advancement of the inquiry and in moral terms.
6. Receiving basic instruments for the performance of the inquiry project from the teacher-mentors in preparation activities.

4.3.2.2.2 Students' Lack of Satisfaction with the Teacher-Mentor's Instruction in the Final Stage (12th Grade)

As noted in the quantitative analysis, slightly less than one-sixth (15%) of the students are not sufficiently satisfied with the teacher-mentor's instruction in the final stage (twelfth grade, N=34) of the inquiry work. These students wrote different reasons for the lack of satisfaction with the instruction. We note that these reasons do not speak about all the teacher-mentors and sometimes a number of arguments are associated with one teacher-mentor.

Causes of the Students' Lack of Satisfaction with the Teacher-Mentor's Instruction are as follows (Appendix 4.3.2 presents examples of student quotes indicate these reasons):

1. Over-involvement of the teacher-mentor in the choice of the inquiry directions and ways of investigation and not giving an adequate space of action to the students.
2. Giving too much responsibility and independence to the student in the learning and investigation of the phenomenon.
3. Lack of response or late response of the teacher-mentor to the questions or the feedback about their work.
4. Expertise of the teacher-mentor in the researched topic.
5. Explanations of the teacher-mentor about the researched phenomenon (they do not suit the student's level of understanding).
6. Instruction that is not focused and dispersion of the teacher-mentor from topic to topic and in investigation directions and does not suit the students' expectations.
7. Lack of complete commitment and focus of the teacher-mentor in the students' work and lack of receiving a personal attitude and caring from the teacher-mentor.
8. Criticism that deters to a certain degree of the academic counselors, when they go around the research teams, and this sometimes, in the students' opinion, gives a feeling of being tested more than being helped.

The students describe suggestions / ways of coping

1. Balance in the teacher-mentor's degree of involvement in the students' inquiry work, on the one hand giving a space for freedom of action and thought in the inquiry work and on the other hand giving support and direction when needed.

2. Response to the students' questions and giving feedback to their work in a continuous and timely manner.
3. Performance of coordination of expectations between the teacher-mentor and the students about the management of the project work and the return of the teacher-mentor's focus to the topic/question in the discussion with the teacher-mentor.
4. Giving a personal attitude to the students and expressing commitment of the teacher-mentor to the project and to teamwork.
5. Follow up after the functioning of the teacher-mentors and classification of the acceptance of the inquiry teacher-mentors to the instruction in the program (it is necessary to accept teacher-mentors who are caring and patient with students who are performing inquiry and who know to instruct inquiry).
6. Reduction of the criticism and giving an equal attitude to all groups on the part of the academic counselors.

4.3.3 Main Findings- Students' Satisfaction with the Instruction of the Teacher-Mentor during the Inquiry Work

The quantitative findings of the research study, in the two stages, the intermediate stage and the final stage of the inquiry work, indicated that most of the students (above 85%) report that they are satisfied with their teacher-mentors' instruction and they are satisfied with their teacher-mentors' cooperation during the inquiry work. There is a decline of about 5% with the student's satisfaction with the instruction from the intermediate stage (91%) to the final stage of the inquiry work (85%). However, a significant change was not found ($p > .05$) between the means of the final stage and the intermediate stage of the inquiry work in their degree of satisfaction (a mean of stage 2 – 3.38 versus out of 4 on a Likert scale, a mean of stage 3 – 3.22 out of 4 on a Likert scale). Both in the intermediate stage and in the final stage of the inquiry work, the mean of the students' satisfaction with the following statements is ranked according to order (from high to low): the physical knowledge of the instruction staff, the response to the questions during the work, support of the instructor in the teamwork, instruction in the choice of the topic and planning of the project, and the least number of students are satisfied with the instruction for the presentation before the peers.

The following table presents a **summary of the main aspects in the students' satisfaction with their teacher-mentor's instruction**, which arose from the students' qualitative responses during the inquiry work (eleventh grade – N=33, twelfth grade – N=34). Appendices 4.3.1, 4.3.2 presents examples illustrating these aspects.

Table 27: Main Aspects in the Students' Satisfaction with the Teacher-Mentor's Instruction (Sigron, M)

Satisfaction with the Instruction	Lack of Satisfaction with the Instruction	Suggestions/Ways of Coping of the Students	Stage
Giving a certain free space in the choice of investigation directions and investigation method, which enables the students to learn and to research independently, to take responsibility for their inquiry work, and to initiate progress in the investigation	Excessive involvement of the teacher-mentor in the choice of the inquiry directions and ways of investigation and not giving a sufficient space of action to the student in the inquiry process	Balance in the teacher-mentor's involvement in the student's inquiry work, on the one hand, giving a space of freedom of action and thought in the inquiry work and on the other hand, giving support, direction, and help when necessary (there are students who seek to give more direction on the part of the teacher-mentors alongside the independent learning and some seek to give more freedom of action and thinking to the student	2, 3
Providing support and direction as necessary alongside the student's independence in the management and leadership of the inquiry	Lack of direction in learning and in investigation and giving too great a degree of responsibility and independence to the student (despite the students' awareness of the importance of independent learning and independent investigation as an inseparable part of the inquiry process)		
Availability and responsiveness of the teacher-mentors to questions, from giving feedback on their work that enables the knowledge to be built and the investigation to be advanced	Lack of responsiveness or late response of the teacher-mentor to questions or to feedback on their work	Responsiveness to the students' questions and giving feedback to their work in a continuous manner and on time	2, 3
Professional accompaniment, of the teacher-mentors and all the instructional staff (academic counselors, laboratory technicians), both in the content of the researched topic and in the accessibility of the content and in the guidance of the inquiry process as a whole	Lack of knowledge of the teacher-mentor in the researched field and in the skills required to advance the inquiry work or giving explanations by the teacher-mentor about the researched phenomenon that are not understood by the student	The adjustment of the teacher-mentor to the student and to the project topic, if there is need to change the teacher-mentor in the middle of the work	2, 3

Cooperation and mutual coordination between the teacher-mentor and the student for requirements and expectations	Guidance that is not focused and scattering of the teacher-mentor from topic to topic and in investigation directions and lack of coordination of expectations	The performance of coordination of expectations between the teacher-mentor and the student over the conduct of the project inquiry	3
Giving a personal attitude and display of empathy to the students, full commitment, and focus on their project	Lack of complete commitment and focus of the teacher-mentor on the students' work and lack of a personal attitude and caring from the instructor	Giving a personal attitude to the students and expression of the teacher-mentor's commitment to the project and the teamwork, classification and acceptance of the inquiry teacher-mentors for guidance in the program and follow up after the teacher-mentors' functioning	3
Openness and trust between the teacher-mentors and academic counselors and students, which enable the students to feel comfortable asking for help both in the advancing of the inquiry and in moral terms	Deterring criticism to a certain extent from the academic counselors, when they go among the research staffs, which sometimes, according to the students, there is a feeling of being examined more than being helped	The reduction of the criticism and giving an equal attitude towards the groups on the part of the academic counselors	3
Receiving basic tools for the performance of the inquiry project from the teacher-mentors in preparation activities in the first year of the inquiry			2, 3

It is possible to see from the table that the students who are not satisfied address the factors that arose from the satisfied students' statements, as well as the suggestions and ways of coping of the students. Hence, it can be assumed that these aspects are equally important to the students, both to those who are satisfied and to those who are not satisfied with the teacher-mentors' instruction.

From the aspects in the table, it is possible to understand how the students perceive the teacher-mentor's role in the inquiry work, in the context of different categories: managing the inquiry work, building content knowledge, and in the context of teamwork in general.

In the context of **the management of the inquiry work:**

- The teacher-mentor's degree of involvement. On the one hand, the giving of a certain free space in the choice of the direction of the investigation, the way in the investigation, in the management and leadership of the investigation enables the student to take responsibility for his inquiry work, to initiate, to learn, and to research independently so as to advance and succeed in the investigation. On the other hand, giving support and direction to the student when necessary, without harm to the students' feeling of independence in the inquiry work.
- Basic instruments for the performance of the inquiry project from the teacher-mentors in preparation activities in the first year of the inquiry that helped them in the continuation use them independently.

In the context of **the building of content knowledge:**

- To provide more direction on the part of the teacher-mentors (alongside independent learning) in the focusing of the theoretical material relevant to the inquiry and in the building of knowledge and understanding of the researched phenomenon.
- Availability and responsiveness of the teacher to questions, providing feedback on their work that enables the building of the knowledge and advancement in the inquiry.
- Experience and expertise of the teacher-mentors (and all the instructional staff, academic counselors, and laboratory technicians), both in the content of researched topic and in the making the content accessible and in the guidance of the inquiry process.
- Giving explanations that will be understood on the student's level.

In the context of **the teamwork between the student and the teacher-mentor:**

- Cooperation and coordination of expectations between the teacher-mentor and the student.
- A personal attitude, commitment, and focus on their projects, support and empathy when they encounter difficulties during the inquiry.
- Openness and trust between the teacher-mentors and the academic counselors and the students, which enable the students to feel comfortable asking for help both in the progress of the inquiry and in moral terms.

4.4 Comprehensive Summary of the Findings for the Second Research Question

This chapter presents a comprehensive summary of the findings that provide an answer to the second research question:

- 2) How did the student perceive the **learning environment** in the 'Research Physics' program along their engagement in the various stages⁷⁰ of the inquiry work? In particular: **roles of students and teachers** and **learning resources**?

Data triangulation from 3 resources:

1. Questions regarding the differences between the instructional lab in the school framework and the "Research Physics" program⁷¹
2. Questions regarding the students' attitudes about the process of inquiry and learning environment in the "Research Physics" program and attitudes about their ability to perform research work and the contribution of the program to their performance⁷²
3. Questions regarding students' satisfaction with the teacher-mentor's instruction⁷³

An overall picture of the research findings in the different sources appears in the following:

⁷⁰ Stages of the inquiry work: a preparation stage for the inquiry project, an intermediate stage, and a final stage of inquiry work.

⁷¹ From the Attitudes Questionnaire (Appendix 1.3). In the questionnaire the students were asked to answer the questions: "In your opinion, to what extent is there a difference between activities in the laboratory in the school and activities you performed in the framework of the 'Research Physics' Program? (Choose from 3 options: large difference / small difference / no difference). If there is a difference, note at least 2 main differences in your response." The questionnaire was held at two times, during the intermediate stage (middle of the eleventh grade, 2.2018) and about a year later in the final stage of the inquiry project work (middle of the twelfth grade, 1.2019), N=33.

⁷² From the self-reporting attitude questionnaires, Attitudes Questionnaire (Appendix 1.3) and the Summative Questionnaire (Appendix 1.4) – questions on a Likert scale (5 levels) that examine the students' degree of agreement with different attitudes on the inquiry process on the 'research physics' environment, on their ability to perform inquiry work, and on the contribution of the program to their performances and in addition, from the open questions in the interviews with eleven students at the end of the eleventh grade. The Attitudes Questionnaire was held at two times, during the intermediate stage (middle of the eleventh grade, 2.2018) and about a year later in the final stage of the inquiry project work (middle of the twelfth grade, 1.2019), N=33. The Summative Questionnaire was held at two dates, at the end of the intermediate stage (eleventh grade 4.2018) and at the end of the final stage of the inquiry work (twelfth grade 5.2019), N=33.

⁷³ From the Summative Questionnaire (Appendix 1.4). In the questionnaire the students were asked to note their degree of satisfaction with their teacher-mentor's instruction on a Likert scale of 1-4 and the factors of their satisfaction/dissatisfaction. The questionnaire was held at two times, towards the end of the intermediate stage (eleventh grade 4.2018) and about a year later towards the end of the final stage of the inquiry work (twelfth grade 5.2019), N=33.

Source 1: Like the research assumption, most of the students see their activity in the ‘Research Physics’ program to be fundamentally different from their activity in the school laboratory environment, both in the intermediate stage (97%) and in the final stage (94%) of the inquiry work, when a significant difference was not found between the stages. The students indicate a difference both in terms of the role of the student and the teacher and in terms of the learning resources given to them. As we will see in the continuation, they emphasized differences mainly in aspects of management of the inquiry work, building content knowledge, teamwork with the partner and with the teacher, and in general comparison to the world of the scientific researcher (for a full description of the quantitative and qualitative analysis see chapter 4.1).

Source 2: Like the research assumption, the students for the most part express positive attitudes towards the inquiry process and the ‘Research Physics’ learning environment, which reflect the epistemology of authentic scientific research, interest, and appreciation towards the scientific research approach. In addition, they express positive attitudes regarding their ability to perform the inquiry work and the contribution of the program to its performance and to their personal growth, mainly in aspects of management of the inquiry work, building content knowledge, teamwork with the partner in the inquiry work and identifying with the world of the scientific researcher. In the aspect of the work in the team with peers in the broader group, the students’ attitudes were less positive (values between 3-4, out of 5 on the Likert scale), when in the rest of the aspects the students’ attitudes are more positive (values above 4 out of 5 on the Likert scale) These findings are strengthened also by the qualitative analysis from the students’ responses in the interviews (for a full description of the quantitative and qualitative analysis see chapter 4.2). Unlike the research assumption, the students’ attitudes in these aspects generally were similar both in the intermediate stage, and in the final stage, in most of the attitudes significant changes were not found between the stages (in the continuation the attitudes in which there was a significant change between the stages were noted). The expectation was that changes would be found in most of the attitudes between the final stage and the intermediate stage of the inquiry work.

Source 3: Unlike the research assumption, most of the students report that they are satisfied throughout the inquiry work from the instruction they received in the ‘Research

Physics' Program, both in the intermediate stage (91%) and in the final stage (85%) of the inquiry work. The expectation is great difference in the students' satisfaction with the teacher-mentors' instruction. In addition, a significant difference was not found in the students' degree of satisfaction with the teacher-mentors between the two stages. The students describe the factors of their satisfaction and the factors of their lack of satisfaction with the teacher-mentors' instruction mainly in the categories of managing the inquiry work, building content knowledge, and teamwork between the teacher-mentor and the students. The qualitative analysis indicates that both the students' satisfaction and lack of satisfaction address the same factors (for a full description of the quantitative and qualitative analysis see chapter 4.3).

Below is an extension on each one of the following categories of the students' perception on the 'research physics' learning environment:

1. The students' perception of the role of the teacher and the student in managing the inquiry
2. The students' perception of the role of the teacher and the student in building content knowledge in the inquiry work.
3. The students' perception of the role of the teacher and the student in teamwork
4. The students' perception of the identifying with the world of the scientific researcher

1. The Students' Perception of the Role of the Student and the Teacher in Managing the Inquiry Work

1.1 The Role of the Student in Managing the Inquiry Work

The students' perception of the student's role in managing the inquiry work, regarding their degree of responsibility and independence in the inquiry work: in the Attitudes Questionnaire (source 2), which was held in the intermediate stage and in the final stage of the inquiry work, the students agree (values of 4-4.5 out of 5 on a Likert scale) that the responsibility for the inquiry process in the project was mainly that of the student, that the inquiry process required commitment and great initiative on the student's part, and that the student experienced independence in the performance of the inquiry activities during the program. We note that this perception of the students was more positive after their experience in inquiry than their perception from the beginning of the inquiry process (values between 3-3.5 as opposed to 4-4.5 out of 5 according to a Likert scale) (chapter 4 – 4.2.1.1.3, 4.2.1.2.1).

These points are supported by the students' comparison of the 'research physics' environment to the school laboratory (source 1), in which they report, both in the intermediate stage and in the final stage of the inquiry work, that their degree of independence, initiative, and degree of responsibility is greater in a learning environment that focuses on inquiry than in the school environment (chapter 4 – 4.1.2.3). In addition, from the Attitudes Questionnaires (source 2) in the two stages most of the students (intermediate stage 94%, final stage 100%) saw themselves as responsible largely for the project success (mean of the student's degree of responsibility close to 5 out of 5 according to the Likert scale). Slightly less, about three-quarters of the students (intermediate stage 70%, final stage 82%) saw it as assigned also to the mentor-teacher (mean of the teacher-mentor's degree of responsibility close to 4 out of 5 according to the Likert scale).

There is a change of perception regarding the role of the laboratory assistance, which is expressed in a trend of increase in the percentage indicating it as responsible for the success of the inquiry project from the intermediate stage (15%) to the final stage (33%) (chapter 4 – 4.2.1.1.1, 4.2.1.1.2). These points are also supported by the interviews (chapter 4 – 4.2.1.1.4), in which the prominent perception was that the responsibility for the inquiry process and for the project success is mainly that of the student but nevertheless the responsibility of the teacher-mentor is necessary and very important (as will be described in the continuation in the students' perception of the teacher's role in the inquiry work).

The students describe the areas of responsibility and independence that are expressed from the beginning of their inquiry work until the end – from the choice of the topic and the inquiry question and choice of the way of investigation (planning an experiment and performing it) until the collection and analysis of the data. During the inquiry work, the students offer new directions of investigation, can change the objectives of the investigation, and reach unexpected places because of the dynamism of the inquiry process and field of interest. To differentiate from the school, the students tell that the teacher chooses the topic researched in the laboratory and decides the direction of the investigation of the laboratory activity, and the objectives of the activities are defined ahead of time from the curriculum of the Ministry of Education (see the quotes in chapter 4 - 4.1.2.1 sections 1-2, 4.1.2.2 sections 1-3).

The points are supported in the interviews (chapter 4 – 4.2.1.2.2) in which the students describe the areas of independence, both in terms of freedom of action in the practical experience (such as organization of the experiment equipment, planning the experiment, and performing the experiment independently) and in terms of the ownership of the making decision on the directions of development of the project. In addition, the students report (in source 1 and in source 2) that in the ‘research physics’ framework they had to organize the inquiry work – to plan the work and the time schedule by themselves (see the quotes in chapter 4 – 4.1.2.1 section 7, 4.1.2.2 section 11, 4.2.1.3.1). In the interviews they describe how things happen in actuality, the use of tools for planning and supervising the inquiry work – through a work journal that includes planning the time schedule and follow up after the work, taking responsibility, and making time available, order and organization in the inquiry work in an ongoing manner (chapter 4 – 4.2.1.3.2).

For the project to be ready and reach its end and meet the level required of the program, the students say that they are required to be serious and self-disciplined, to invest considerably, and to do the best they can, since otherwise the inquiry work will not be meaningful and complete (chapter 4 – 4.2.1.1.4). Accordingly, when they were asked in the attitudes questionnaire (source 2) what the experience in the inquiry activity in the program contributed to them the students agree (values between 4.5-5 out of 5 according to a Likert scale) that the experience cultivated their personal responsibility for the learning and the good performance of the work, trained them to have independent ability, and allowed the cultivation of the student’s initiative (chapter 4 – 4.2.1.1.3, 4.2.1.2.1). In addition, they note that the program improved (mean close to 4 out of 5 according to a Likert scale) their ability to plan and organize the work and developed in them critical and reflective thinking on the inquiry work (chapter 4 – 4.2.1.3.1).

Coping with the dynamism of the inquiry and with situations of uncertainty during the inquiry work and the development in the perception of the self-efficacy: responsibility and considerable independence can be perceived as frustrating, as not possible to fulfill. The student does not succeed in bringing the work to a successful conclusion or on the contrary, as an opportunity for learning. From the Attitudes Questionnaires (source 2) both in the intermediate stage and in the final stage of the inquiry work the students recognize that the research is a dynamic process, when the directions of investigation and directions of inquiry can change during the work and the coping with the dynamism of the inquiry, with mistakes

and search for solution are the opportunity for learning and a natural part of the inquiry process (values between 4-4.5 out of 5 according to a Likert scale). There is even a significant increase in this perception from the intermediate stage to the final stage of the inquiry. In the two stages, they agree (values between 4-4.5 according to a Likert scale) that the inquiry activity set for them challenges and coping with complex and open problems and that they experience coping with conditions of uncertainty and frustration during the inquiry work (chapter 4 – 4.2.1.4.1).

From the comparison of the research environment to the school laboratory (source 1) the students relate that in the final stage of the inquiry work they coped with more complex challenges than in the school during the inquiry work, such as making decisions, learning from mistakes and failures, coping with situations of powerlessness (see the quotes in chapter 4 – 4.1.2.2, section 12). Also it arises from the interviews (chapter 4 – 4.2.1.4.2) that they have a change in the conduct and perception of the inquiry process, which is expressed in the readiness and understanding that these copings are a natural part of the inquiry process, the development of adjustment ability (resilience and flexibility) to situations of uncertainty and dynamism in the inquiry work, recognition that determination and development of creative thinking enable the solving of problems that appear during the inquiry and departure from a situation of uncertainty or what appears to them as a dead end. Accordingly, it is not surprising that the students agree (values between 4-4.5 out of 5 according to a Likert scale) both in the intermediate stage and in the final stage of the inquiry program that the experiences in the inquiry activity in the program contributed to the development of resilience and flexibility in the coping with situations of uncertainty and with frustrations and to the development of creative thinking (chapter 4 – 4.2.1.4).

An important indicator of the practices that they believe they have acquired is the experience that they can (high mean about 4.5 out of 5 according to a Likert scale in the intermediate stage and final stage of the inquiry work) cope with a new inquiry project in addition with relative ease (chapter 4 – 4.2.1.4.1). The change in the perception of their self-efficacy arises also in the interviews (chapter 4 – 4.2.1.4.2), which is expressed in the reduction of the concern regarding the coping with new things or ‘failures’ (in the student’s eyes) and in their belief in themselves that they can perform inquiry work and deal with the difficulties posed by the inquiry.

1.2 The Role of the Teacher in Managing the Inquiry Work

The students' perception of the teacher's role of the degree of responsibility in the students' inquiry work: As noted above, students state that the teacher-mentors also have great responsibility for the success of their inquiry project, although the perception that the main responsibility is that of the student was prominent. The statements are also supported in the interviews (chapter 4 – 4.2.1.1.4). The students note that the teacher-mentor's responsibility is essential and very important, and through it the inquiry project advances and the quality of the project improves. It is possible to see from the students' explanations their perception of the areas of responsibility assigned to the teacher-mentor. In their opinion, the teacher-mentor's responsibility is mainly to provide an answer to the problems that the students cannot answer by themselves, to provide a theoretical and planning-oriented overall picture and direction and support as needed (chapter 4 – 4.2.1.2.2). In addition, the students noted that obtaining basic tools and practices for the inquiry from the teacher-mentors in the preparation activities helped them use them in the continuation of the inquiry work (see the quotes in chapter 4 – 4.3.12.1 section 4, 4.3.2.2.1 section 6).

Furthermore, it is possible to see from the comparison of the 'research physics' environment to the school laboratory (source 1) that in the students' eyes the teacher's role in the environment that focuses on the inquiry project is to provide a space for action and independence for the student throughout the inquiry work and to allow the student to lead the inquiry work. Simultaneously the teacher-mentor guides as necessary and supports emotionally and in terms of morale, so that the student will be an independent and initiating researcher. To differentiate from the school, according to the students' reports, the teacher leads the laboratory activity and manages the lesson and the schedule of the laboratory activities. In addition, the students say that in most of the laboratory activities in the school the teacher provides a full laboratory briefing – from providing the goal of the experiment and the performance instructions to writing the experiment conclusions, and the student works according to the instructions and there is not really room for the student's independent thinking and acting. Thus the students less cope with challenges innate in inquiry (such as continuous search for an answer, trial and error, and dealing with situations of uncertainty) and are less independent in the performing of laboratory activities (see the quotes in chapter 4 – 4.1.2.1 section 7, 4.1.2.2 section 11).

Even when the students described the factors of their satisfaction or dissatisfaction with their teacher-mentor's instruction (source 3) the students address the teacher-mentor's degree of involvement in the instruction of the inquiry work. On the one hand, the teacher-mentor gives a certain free space in the choice of the direction of the investigation, the way of the investigation, the management and leading of the investigation, which enables the students to take responsibility for their inquiry work, to initiate, to learn, and to research independently to advance and succeed in the investigation. On the other hand, the teacher-mentor provides support and direction to a student as needed without harming the students' sense of independence in the inquiry work (see the quotes in chapter 4 – 4.3.1.2.1 section 1, 4.3.1.2.2 sections 1-2, 4.3.2.2.1 section 1, 4.3.2.2.2 sections 1-2).

These points are supported also from the students' responses in the interviews (chapter 4 – 4.2.1.2.2 and 4.2.1.3.2). In the interviews, the students attribute the experience of independence and initiative in the performance of the inquiry work to the teacher-mentor's degree of involvement: the teacher-mentor on the one hand gives time and a space for action to the students in the performing and planning of the experiments and enables the student to manage the research work independently, while on the other hand, the teacher-mentor advises as needed, gives an equal status to the student to resolve disagreements on different aspects in the project, and the student's desire has decisive weight in the project's directions of development. In addition, the students note that they are also interested in receiving advice from their teacher-mentors in the planning and organization of the research and the setting of objectives for the work in the coming sessions (chapter 4 – 4.2.1.3.2).

In addition, the students attribute their experience of independence and initiative to the inquiry style – semi-open inquiry (between guided inquiry and open inquiry), in which the teacher-mentor does not provide answers to students but obligates them to discover them on their own and does not limit them conceptually and practically in the laboratory, in order to allow them to cultivate their initiative and independence. However, there are students who described the teacher-mentor's involvement in that they are less given independence during the performance of the inquiry (or they are given only towards the end of the research), they were not satisfied with this, and they were interested in being given more independence and room to make their own decisions (chapter 4 – 4.2.1.2.2).

Alongside the importance of giving independence to the student in the inquiry work, the interviews indicate that it is important to the students to also receive close accompaniment and a personal attitude from their teacher-mentor (chapter 4 – 4.2.1.2.2.). Some of the students note the importance of the personal attitude, support, and direction of the teacher-mentors especially in situations of powerlessness and frustration. In their opinion, the teacher-mentor’s support of the management of the inquiry work is expressed in the observation and reflection on what is done, shared decisions on what to focus, giving hints and suggestions for directions of investigation, in general encouragement and motivation on the teacher-mentor’s part to continue and to advance in the investigation. Furthermore, the students relate that the teacher-mentors give them the confidence to be in situations of uncertainty or to cope with the dynamism of the inquiry or with ‘failure’ (in the student’s eyes), since they are an inseparable part of the inquiry process. This is through the personal relationship of the teacher-mentor, the creation of relations of trust and openness with the students (chapter 4 – 4.2.1.4.2).

2. Perception of the Students of the Role of the Student and the Teacher in Building Content Knowledge in the Inquiry Work

2.1 Role of the Student in Building Content Knowledge in Inquiry Work

The students’ perception of the student’s role in the building of the content knowledge in the inquiry work: in the learning environment that focuses on inquiry the student is required to be involved and active in the building of the theoretical knowledge and to have a significant part in the learning process. In the Attitudes Questionnaire (source 2) in the intermediate stage and in the final stage of the inquiry work, the students agree (values between 4-4.5 out of 5 according to a Likert scale) that learning through inquiry is the student’s independent and active learning, which enables the student to be involved in the learning and to build his knowledge by himself. In addition, in the two stages the students agree (values between 4-4.5 out of 5 according to a Likert scale) that in the program there were many opportunities to participate actively in the learning process and to build the knowledge themselves and they experienced independent learning and active learning (chapter 4 – 4.2.2.1).

The students describe the way in which they build the content knowledge. In the interviews (chapter 4 – 4.2.2.2) the students emphasize that unlike the school in most of the inquiry process they themselves build the knowledge and not the teacher and considerable active learning and independent learning of the student are required, alongside the support from the teacher-mentor. To differentiate from the school, in which the teacher generally defines the knowledge learned adjacent to the curriculum of the Ministry of Education and builds it for the student during the lesson (see the quotes in chapter 4 – 4.1.2.1 sections 4-6, 4.1.2.2 sections 5-9). In the interviews (chapter 4 – 4.2.2.2) the students describe actions that they needed to build their knowledge, such as the search for information sources relevant to the inquiry, organization of the new information, disclosure of the relationship between the variables in the experiment, understanding the meaning of the formula, giving an explanation / explanations for the researched phenomenon, use and implementation of the acquired knowledge for the continuation of the investigation.

From the students' comparison of the research physics environment to the school laboratory (source 1), it is possible to also see how the students act to build the knowledge. Both in the intermediate stage and in the final stage of the inquiry work, the students report that in the framework of research physics they are responsible for their learning and for the pace of the learning progress, they set for themselves goals for learning and make different decisions (such as choosing learning contents and degree of depth of learning in these contents), and last they perform supervision and control over their learning. In the interviews, the students note that the building of the knowledge entails the independent search for and organization and learning of information sources, so that there will be knowledge and in-depth understanding of the researched phenomenon. In addition, the students note that following their active and independent learning they build themselves new knowledge for themselves also in the contents that are beyond the curriculum and they broaden their horizons (see the quotes in chapter 4 – 4.12.1 sections 4-6, 4.12.2 sections 5-9).

In addition, the students focused (in source 1) on that in the 'Research Physics' program for the most part the building of knowledge is based at first on the analysis of the findings from the experiment and on this basis the students learn the theory. In other words, the practical experience (performing experiments in the laboratory) precedes the learning of the theory or is in parallel to it. This is different from the school, where according to the

students' statements generally the building of the knowledge is based first on the theory and on this basis experiments are performed (see the quotes in chapter 4 – 4.1.21 section 3, 4.1.2.2 section 4). In the interviews (chapter 4 – 4.2.2.2) students emphasized the uniqueness of the learning in the inquiry way in the programs in the way in which they build the content knowledge. The students tell that for the most part the building of the knowledge and the learning of the theory was during the practical experience (performance of the experiment) or after it, and the experiment caused them to understand the theory better and not as generally is done in the school where for the most part the theoretical explanation precedes the experiment.

Accordingly, it is not surprising that in the Attitudes Questionnaires (source 2) the students agree (values between 4-4.5 out of 5 according to a Likert scale) that the learning through inquiry in the program contributed to the development of their ability of active learning and independent learning, strengthened their knowledge in the scientific content (particularly in physics), advanced their understanding of physical concepts and principles in an in-depth manner, and broadened their knowledge of physical topics that were beyond the curriculum in the school (chapter 4 – 4.2.2.1). In the interviews (chapter 4 – 4.2.2.2) the students note that building knowledge in a lengthy inquiry process yields an in-depth understanding of the behavior of the researched phenomenon and the theory that explains it. Moreover, the students add that the experience in the building of knowledge in inquiry increases the student's sense of self-efficacy in the learning of theoretical material new to him and in his ability to learn it independently.

2.2 The Role of the Teacher in the Building of Content Knowledge in the Inquiry Work

The students' perception of the teacher's role in building content knowledge in inquiry work: From the students' comparison of the 'research physics' environment to the school laboratory (source 1) in the students' eyes, the teacher-mentor must inspire challenge and curiosity also in contents beyond the curriculum. In addition, the teacher-mentor must provide contexts and constitute a source of information but not an exclusive source and to help if necessary the student build the knowledge by himself. To differentiate from the school, in which the teacher generally reveals the information, as the main source, and builds it for the student (see the quotes in chapter 4 – 4.1.2.1 section 3, 4.1.2.2. section

4). In addition, the students sought (source 3) in the intermediate stage of the inquiry work that the teacher-mentor will help with the focus of the theoretical material relevant to the inquiry and the building of the knowledge and the understanding of the researched phenomenon, such as giving more information sources relevant to their inquiry, preliminary explanation of the physical concepts and principles related to the phenomenon and instruction of the complex ways of data analysis (see the quotes in chapter 4 – 4.3.1.2.2 section 1).

The statements are supported by the interviews (chapter 4 – 4.2.2.2). In the interviews, the students report that alongside their independent learning and active learning in the inquiry work it was necessary to have collaborative learning with the teacher-mentor when they did not succeed in building the knowledge by themselves. In their opinion, the teacher-mentor must stimulate and inspire curiosity among the students for other things that are relevant to their inquiry. Simultaneously they must focus the students and simplify the complex material for them, in order to advance them in the research and to develop their independent learning ability.

In addition, the students relate (in source 1) that the teacher-mentors give them the time to deal with challenges and do not immediately give explanations and the answer to the challenge, as generally is done in the school, and enable the student to search for the answer from his practical experience and in information sources (see the quotes in chapter 4 – 4.1.2.1 section 3, 4.1.2.2 section 4). From the interviews (chapter 4 – 4.2.2.2) in the students' eyes the teacher-mentor needs to encourage the student towards independent learning in the inquiry work, to enable the student to cope with the challenge innate in his learning, and to give the time to overcome them through support and direction as necessary. The students attribute their sense of self-efficacy to learn material independently to the teacher-mentors who gave the necessary time to the search for the answer and did not immediately bring the answers.

In other words, according to the students, the teacher-mentor's role is to provide an answer to questions that they cannot solve themselves but not necessarily only in the giving of explanations but also in the direction and encouragement to search for other sources and solutions that will help them find the answer to their question. In addition, the issue of the tackling of formulas – according to the students' report in the final stage of the inquiry

work, unlike the school, in the ‘research physics’ program the teacher-mentors do not let the students learn by rote and practice the formula relevant to the researched content (as generally done in the school). Rather, for the most part they provide the necessary time for the students to develop the formula, to understand its components, its goal, and how it is created from the answers obtained in the experiments. In this way, the teacher-mentors enable the student to build the knowledge by himself (see the quotes in chapter 4 – 4.1.2.2 section 10).

In addition, when the students detailed the factor of their satisfaction or lack of satisfaction with their teacher-mentor’s instruction (source 3), the students addressed both in the intermediate stage and in the final stage of the inquiry work the importance of the teacher-mentors’ availability and response to the students’ questions and providing feedback to their work, which enable them to build their knowledge and advance in the investigation. Furthermore, the students addressed the importance of the teacher-mentors’ professionalism (and of the entire instructional staff – academic counselors and laboratory assistants) so that they can help them with building the content knowledge – the students expect that the teacher-mentors will have experience and expertise, both in the content of the researched topic and in the accessibility of the content and the instruction of the inquiry project, and that the teacher-mentors’ explanations of the researched phenomenon will be understood at the student’s level (see the quotes in chapter 4 – 4.3.1.2.1 sections 2-3, 4.3.1.2.2 section 3, section 1, 4.3.2.2.1 section 2, 4.3.2.2.2 sections 3-4).

3. The Students’ Perception of the Role of the Teacher and the Student of the Teamwork in the Inquiry Work

3.1 The Role of the Student in the Teamwork during the Inquiry Work

The students’ perception of the student’s role of the teamwork with the project partner: From the research findings it is possible to see that the students perceive the collaborative learning and teamwork with the project partner as vital and important practices in the inquiry work and in general. In the Attitudes Questionnaires (source 2), both in the intermediate stage and in the final stage of the inquiry work, the students agree (values between 4-4.5 according to a Likert scale) that the research done in pairs is more

productive than research done by a single researcher. The students agree (values between 4-4.5 according to a Likert scale) that performing an inquiry done in pairs enabled experience in peer learning and experience in teamwork (chapter 4 – 4.2.3.1). In the interviews (chapter 4 – 4.2.3.2) all the students who were interviewed (eleven students) prefer working with a partner and not alone in inquiry work because of its advantages (as detailed in the continuation). In addition, according to the students' reports, the comparison of the 'research physics' environment to the school laboratory (source 1) indicates that in the 'research physics' program many opportunities are given for the long-term (the students' work is done in regular pairs every week for two continuous years). This is to differentiate from the school, in which few opportunities were given for teamwork and many more are performed individually and generally the work task in the group in the laboratory is for the short-term, one or two lessons (see the quotes in chapter 4 – 4.1.2.1 section 8, 4.1.2.2. section 13).

In addition, the students describe the **actions that occur in teamwork with the project partner**. The students relate (in source 1), both in the intermediate stage and in the final stage of the inquiry work, in the 'research physics' framework they performe together practical inquiry (that includes the entire experiment design), talk about the researched phenomenon, bring up difficulties and problems and think together about solutions, give and receive feedback from one another, ask for help from the peer and use the strengths of one another to find ways to advance their learning and to contribute to their peers' learning (see quotes chapter 4 – 4.1.2.1 section 8, 4.1.2.2 section 13).

From the interviews (chapter 4 – 4.2.3.2) the students describe the advantages of the teamwork: mutual fertilization in the understanding of the theory and the ways of investigation, brainstorming to produce ideas and possible solutions for problems, division of work to increase efficiency and advance in the inquiry, acceptance of one another according to their strengths. In addition, the students learned from the teamwork about themselves that they can work in a team (which was not obvious) and that they improved social skills required for this such as willingness to compromise (tolerance, attention, accepting criticism, mutual respect, and holding ability), confidence in the project partner as possible to rely on him, commitment to the project partner to carry out his part in the

project, support and reinforcement of the partner (especially in situations of frustration), and also enjoyment from joint doing and the friendships created.

These points are supported by the students' statements in the comparison of the research environment to the school laboratory (source 1), in which the students report that they discovered the importance of the teamwork in the inquiry work and its advantages especially in work in the framework of the 'research physics' program in which there is mutual fertilization between the team members, division of work, shared decisions, mutual commitment to the project success (personal responsibility alongside the mutual responsibility), and development of social skills in the teamwork (like giving help, consideration of the pace of learning of the project partner, and listening and accepting the other's opinion) (see the quotes in chapter 4 – 4.1.2.1 section 8, section 4.1.2.2. section 13). Accordingly, when they were asked in the Attitudes Questionnaire (source 2) what the experience in the inquiry activity in the program contributed to them the students agree (values 4-4.5 out of 5 according to a Likert scale) that the performance of inquiry in the program developed in them abilities of teamwork and peer learning (such as cooperating with the team members, listening, accepting another person's opinion, sharing deliberations with others, brainstorming, expressing the self in the team, and discussing reflectively) (chapter 4 – 4.2.3.1).

Perception of the students of the student's role of the teamwork with the peers in the broader group: In the Attitudes Questionnaire (source 2), both in the intermediate stage and in the final stage of the inquiry work, the students do not see with complete agreement (values between 3.5-4 out of 5 according to a Likert scale, these value are not high relative to the other attitudes in the other aspects) that the peer evaluation of the broader group is an inseparable part of the scientific inquiry process. In addition, the students do not see with full agreement (values between 3-3.5 out of 5 according to a Likert scale, these values are low relative to the other attitudes in the other aspects) that time was dedicated to peer assessment in the broader group in the performance of inquiry activities in the program. Accordingly, the students do not see with full agreement (values between 3.5-4 out of 5 according to a Likert scale, these values are low relative to the other attitudes in the other aspects) the contribution of the experience to the improvement of their performance ability in peer assessment and there is even a significant decline between the

intermediate stage and the final stage of the inquiry work in this issue (chapter 4 – 4.2.3.3). The statements are also supported in the interviews (chapter 4 – 4.2.3.4). The students note that enough activities of peer assessment in the broader group were not held during the inquiry work. In addition, infrequently mutual assistance occurred between other teams. One of the explanations according to the students is that it is reasonable to assume that each research team engaged in another inquiry field (so that it could not help another team that is working in a different field of knowledge), as well as students were busy and focused on their inquiry work, who did not have time to help others.

In addition, when the students were asked (in source 3) to note their degree of satisfaction with the cooperation between them and the teacher-mentors in different statements, both in the intermediate stage and in the final stage of the inquiry work, the students were less satisfied (relative to other statements) with the instruction they received before the presentation in front of their peers (chapter 4 – 4.3.1.1, 4.3.2.1). However, in the interviews (chapter 4 – 4.2.3.4) the students ask the teacher-mentors to create more social interactions and particularly to hold more activities of assessment with peers in the broader group during the program, since they are aware of the importance of their participation in this activity. In the interviews they describe the **reasons for the importance of the performance of peer assessment in the inquiry work**: peer assessment focuses the students and contributes to their progress in the inquiry work, because they received constructive and real feedback from their peers, which includes recommendations for the improvement of the work and proposals for the continuation of the investigation. In addition, the peer assessment gives them satisfaction and confidence about their work and their presentation and in parallel exposes the students to other researches of their peers in the broader group. In addition, the students say that in general the mutual assistance of the broader group gives a convenient learning atmosphere, good and fun.

3.2 The Role of the Teacher in Teamwork with Students during the Inquiry Work

The perception of the students of the teacher's role of the teamwork with his students: When the students detailed the factors of their satisfaction or lack of satisfaction with their teacher-mentor's instruction (source 3), in the final stage of the inquiry work the students note the importance of performing coordination of expectations between the

teacher-mentor and the students over the conduct of the project work and the importance of cooperation with the teacher-mentor so that there will be good and effective teamwork. The students report that they expect from the teacher-mentor to obtain a personal attitude, commitment to and focus on their project, and support and empathy when they encounter difficulties that the inquiry poses. In addition, the students note that there is need for openness and trust between the teacher-mentors (and the academic counselors) and the students to enable them to feel comfortable to ask for help both in the progress of the inquiry and in moral terms (see the quotes in chapter 4 – 4.3.2.2.1 sections 3-5, 4.3.2.2.2 sections 6-8).

In addition, from the comparison of the ‘research physics’ environment to the school laboratory (source 1) the students report that in the intermediate stage and in the final stage of the inquiry work that they receive a more personal attitude from their teacher-mentor in the research physics framework than from the teacher in the school, because of the close work with the teacher-mentor over a long period of time (every pair of students has a close teacher-mentor for the duration of the entire inquiry work). The **personal attitude is expressed** in the teacher-mentor’s personal follow-up after the team of his students and in the great availability to his students during and after the sessions. When the teacher in a large class finds it harder to provide a personal attitude and is not always available for his students, there is no close follow up after the student’s work during the lesson and generally the teacher knows the situation of the class only after a test (see the quotes in chapter 4 – 4.1.2.1 section 9, 4.1.2.2 section 14). In addition, in the final stage of the inquiry process some of the students note (in source 1) that the teacher-mentor involves them in the investigation, since he also does not always know the answer to the inquiry question, like them, the teacher-mentor is found ‘at eye level’ with the student and this gives the feeling of true partnership. This is to differentiate from the teacher of the school, who for the most part knows the answers before the laboratory activity and does not research along with the students the observed phenomenon (see the quotes in chapter 4-4.1.2.2 section 15).

4. The Students' Perception of the Identifying With the World of the Scientific Researcher

The students' perception of the identifying with the world of the scientific researcher (including learning resources available to them in the research physics environment): From the interviews (chapter 4 – 4.2.4.2) and from the comparison of the 'research physics' environment to the school laboratory (source 1), the students describe the uniqueness of the 'research physics' program as an environment similar to the laboratory environment of the scientific researcher, which exposes them and brings them closer to the scientist's world more than the school. The students detail the **reasons that caused them to feel identification with the scientific researcher's world**": in the 'research physics' environment they have at their disposal learning resources – diverse and sophisticated equipment for the performance of experiments and the processing of data, meaningful time to carry out full and in-depth inquiry (long term research), close guidance of the experts (teachers with the experience to guide inquiry), as the scientific researcher has. The students note that these learning resources enable them to carry out broad and deep inquiry (see the quotes in source 1 chapter 4 – 4.1.2.2 section 17, quotes from the interviews chapter 4 – 4.2.4.2). In addition, the statements are supported quantitatively by the Attitudes Questionnaire (source 2) that were conveyed to them in the intermediate stage and in the final stage of the inquiry work. In the two stages, the students agree (values between 4-4.5 out of 5 according to Likert scale) since the inquiry activities need to be held under conditions of research to the students (such as sophisticated laboratory and equipment, support of the experts, teacher-mentors, laboratory assistants, and scientist) so as to allow familiarity with the world of the scientific research (chapter 4 – 4.2.4.1).

In addition, the students note (in source 1) in the intermediate stage of the inquiry work that the style of experiments in the 'research physics' environment, their level, and their goal provide them with a feeling of identification with the scientist. The students describe that the experiments in this environment are long-term, because of the constant improvement of the system of experiments and repeated experiments in order to obtain more accurate results. In addition, the students use complicated equipment, like technological instruments (sensors, simulations, electronic spreadsheet) and a

computerized laboratory (computational modeling in Matlab language) that requires a high level of performance. In contrast, in the physics laboratory in the school the students describe that generally the experiment is performed one time during the year and they have sparse and less sophisticated equipment (see the quotes in chapter 4 – 4.1.2.1 section 12). The statements are supported in the interviews (chapter 4 – 4.2.4.2). The students note that the style of the experiments carried out in the ‘research physics’ program are different from the experiments in the school laboratory: the experiments that are performed in the program are more complicated than in the school both because of the requirement for improvement of the system to have accuracy of the measurements and because of the depth of the inquiry and the high level of the data processing.

Another reason that arises from the interviews (chapter 4 – 4.2.4.2) that give students the experience of “being a scientist” is that the results of the experiments are not known ahead of time and the students need to discover the results by themselves and to plan the ways of investigation, to differentiate from the school, where for the most part the results of the experiments are expected by the students and they know what to do according to the directives of the guidelines given to them beforehand. These points are also supported in the comparison of the ‘research physics’ environment to the school laboratory (source 1). Both in the intermediate stage and in the final stage of the inquiry work, the students note that the objective of the experiment is not necessarily to confirm the theory (as generally done in the school laboratory) but for the most part the results of the experiment are not known ahead of time. Although the students emphasize that in the research physics program there is room for unexpected experiment results (which are not commensurate with the theory) and they constitute a motivation to examine the gap between the experiment findings and theory and in-depth investigation, it is necessary to search for and give explanations for these discrepancies, as the scientist does (see the quotes in chapter 4 – 4.1.2.1 section 11, 4.1.2.2 section 16).

In addition, the students emphasize in the interviews (chapter 4 – 4.2.4.2) and in the comparison of the ‘research physics’ environment to the school laboratory (source 1) that in the ‘research physics’ environments they felt the “experience of being a researcher” mainly because they understand the nature of the inquiry process, as a scientist understands, from the search for the problem and its definition to the finding of

a solution for it. In addition, the very experience of considerable practical experience in the 'Research Physics' program more than in the school gives the students the experience of 'being a scientist' (see the quotes in chapter 4 – 4.1.2.1, section 10). Furthermore, in the interviews (chapter 4 – 4.2.4.2) some of the students expressed interest in engaging in research in the future following this experience. These points are supported quantitatively by the attitudes questionnaires (source 2), in which they agree greatly (values close to the value of 4.5 out of 5 according to a Likert scale) both in the intermediate stage and in the final stage of the inquiry work that performing the inquiry project in the 'Research Physics' program was interesting and challenging and they felt that they are performing the work of a scientist-researcher.

Moreover, they are interested (values between 4-5 out of 5 according to a Likert scale) in dealing in the future with a research project. However, there is a significant decline from the intermediate stage to the final stage on the issue of the desire to cope in the future with the inquiry project, but the degree of agreement is still high in the final stage of the inquiry work (value 4 out of 5 according to a Likert scale). Accordingly, when they were asked what the experience in inquiry activity in program contributed to them, both in the intermediate stage and in the final stage of the inquiry work, the students agreed (values between 4-5 out of 5 according to a Likert scale) that the 'Research Physics' program contributed to the development of curiosity for the studies of science and investigation of physical phenomena in particular, like the scientific curiosity of the researcher. The perception, with almost complete agreement (values above 4.5 out of 5 according to a Likert scale) that the program contributed to the improvement of their knowledge and understanding about the inquiry process and about the inquiry skills as required of the scientific researcher, was especially prominent (chapter 4 – 4.2.4.1).

5. Discussion

5.1 Discussion

This part will present a summary and discussion of the main findings of the research, which includes interpretation of the findings and contribution of the present research study, through their connection to the literature, in order to see the research findings in light of what previous research studies have found. At the end of the discussion, the research limitations and suggestions for continuation research will be presented.

The call to integrate scientific inquiry in the school – a process of the search for a solution to a problem that is not well-defined, with focus of the problem and design of ways to solve it – has continued from the start of the 20th century (Dewey, 1938) until today in central position documents (NGSS 2013, NRC 2000, 2012). In particular, they call to allow the students to experience a process of search under conditions of uncertainty and a process of characterization and explanation of the phenomenon in the real world. In the background of the research study, there is the recognition of the importance of in-depth research practices as learning goals for high school physics students. Conversely, in reality it is very difficult to develop such practices in the schools because of the many constraints existing in a system oriented on standardized tests (such as the high school matriculation examinations). This system generally does not leave time for the lengthy work processes that characterize research, with a teaching staff possessed of knowledge focused on the specific curriculum, which mainly addresses known and short problems and not open-ended problems that invite research, and with poor equipment resources and technical support.

In Physics instruction, experimental inquiry activities are integrated in course settings that differ in their structural features (e.g. designated hours, available equipment), in the scope and depth of the experimental research practices that students experience (Holmes & Wieman, 2016). At one end are inquiry oriented instructional labs accompanying Introductory Physics courses (Etkina, Murthy & Zou, 2006; Gandhi, Livezey, Zaniewski, Reinholz & Dounas-Frazer, 2016; Kapach, 2014). These labs are limited in terms of resources such as equipment and instructional time, thus restricting the scope and depth of inquiry experiences. At the other end are supplementary frameworks for capable and talented

students, allowing a prolonged, wider and deeper research experience, for example, research apprenticeship programs advised by scientists in their research labs (Sadler, Burgin, McKinney & Ponjuan, 2010) or research projects advised by teachers in well-equipped advanced school labs (Kapon, 2016). How do students experience inquiry in such contexts?

This research examines this question in a framework in which the extent of constraints removed is very large (in other words, the venture is based on relatively great freedom of action from the viewpoint of the time constraints, equipment, and teaching personnel) – the "Research physics" program – a new school subject in the Israeli education system. It extends for 3 years (10th-12th grade), and incorporates a progression of activities from small scale inquiry to a long-term research project performed in research teams of two students, extending over 1.5 years (before that the students received preparation for over a year). It takes place in highly equipped labs (Davidson Institute, Weizmann Institute of Science, Israel) with professional laboratory technicians and dedicated research advisors that participate in parallel in a supportive professional development program. In this context, the research examined students' views with regard to various inquiry components.

The uniqueness of the research study is not only its focus on a unique framework but also its comprehensive analysis of the perceptions of the physics students of the inquiry process in the long term (over the course of three years). The research study examined the students' outlooks regarding the different inquiry components, particularly, the degree of experience in the performance of these components, the challenges they faced, and their relationship to their personal development throughout the stages of program. In addition, the research study examined the students' perceptions of the "Research Physics" learning environment and its contribution to their personal growth, especially their perception of the roles of the student and the teacher, supports and learning resources they received in the framework of the program, and their satisfaction from it. The research study integrates detailed analysis, as conditional and qualitative, which are based on the students' self-reports (questionnaires and interviews) throughout the main milestones during their inquiry work (preparation stage, intermediate stage, and final stage of the inquiry work) and on the observations in the program sessions.

The principles of design facing the developers of the “Research Physics” program are in general to adopt the principles of cognitive apprenticeship, which place the learner in authentic situations, when the learner works with a talented expert who guides the learning process. Through cognitive mentoring the student can acquire, develop, and use cognitive instruments in the authentic space, and the student learns to take part in the scientist’s world (since the students receive control and considerable ownership of their work throughout the entire inquiry process). In this way, the system of relations with the expert is an important component in the learning process, the teacher serves as a mentor for his mentees, and the teacher illustrates the characteristics of the successful researcher and focuses on the student’s development and the project product. Thus, the research experience between the mentor and the mentee is joint, and serious and collaborative interaction is created between them, with the use of authentic activity as a meaningful part in the learning (Collins, Brown, & Newman, 1989; Osborn & Karukstis, 2009).

In the “Research Physics” program, the objective is to allow the student to participate in authentic activity that characterizes the field: semi-open inquiry, which is also called coupled inquiry, which combines guided inquiry with open-ended inquiry and constitutes an intermediate level between these two levels (Ben-David, 2012; Martin-Hansen, 2002). The activity is supported by scaffolding that is fading, so that the inquiry at first is supported by many scaffolds of structuring and problematizing (see chapter 1, section 1.3.4.2) and in the continuation steadily greater autonomy is transferred to the student, and the student’s degree of independence steadily increases over time (Collins et al., 1991; Reiser, 2004). Throughout the inquiry work, the students are helped by teacher-mentors, as support for their independent work in the understanding of the scientific topic, in the acquisition of tools and methods for ways of investigation and for planning the investigation, in the management of the inquiry, and in the help with the internalization of the inquiry process as a whole and its components.

It is possible to see from the research findings that the students notice the uniqueness of the learning through inquiry in the “Research Physics” framework primarily in the role of the teacher and the student that are realized in this environment, which led to changes in their perception of the nature of scientific research, interest, and self-efficacy. The perception of the roles of the student and the teacher addressed different viewpoints

and were divided into categories (see the summary in chapter 4, section 4.4): building content knowledge, managing the inquiry work, work in a team (between the partners in the project team, between the partners and the teacher-mentor), and in general the similarity of the environment to the work of the scientific researcher.

In the present research study, the students emphasized the uniqueness in the way in which they are involved in the **building of the content knowledge**. The students tell that for the most part the learning of the theory was during the practical experience (performance of the experiment) or after it, and not as generally done in the school, when for the most part the theoretical explanation precedes the experiment. The students note that the building of knowledge in this way yields an in-depth understanding of the behavior of the researched phenomenon and the theory that explains it. In addition, in the present research study the students explicitly note that in the school the teacher/student knows for the most part the results of the experiment in the laboratory ahead of time and generally the aim of the experiment and its conclusions is to confirm the theory learned in the classroom. In contrast, in the performance of the inquiry in the “Research Physics” program, the students do not know the results of the experiment ahead of time to them and the teacher does not necessarily know them either. However, the students emphasize that there is room in the program to research unanticipated results, which are not commensurate with the theories they learned and that the search for the solution gives them the experience of “being a scientist”. Chinn and Malholtra (2002) explain that there are significant differences between experiments carried out by scientists and experiments carried out by students in the school. They hold that the differences derive from the different approach of the performers of the experiments and the outlooks of the students and the teachers on the perception of the laboratory and the ways of carrying it out, and as a result of these differences the cognitive processes that the experiment performers undergo are different.

Additional research studies maintain that the science teachers in the school tend to see science to be a rigid body of knowledge and to address scientific ideas as right or wrong, and from their perspective an experiment is supposed to provide a clear and immediate answer in order to confirm the theory learned in the classroom, and they are not aware of the fact that there are developments in the acquisition of the knowledge of science (Kapach, 2014; Sandoval, 2003; Wieman & Holmes, 2015). Furthermore, the research findings

indicate that in the students' eyes the degree of independence and degree of responsibility of the student for building the content knowledge (about the learning and the pace of progress of the learning) is greater in a learning environment that focuses on inquiry than in the school environment and that the responsibility for the learning through inquiry in the project was mainly on the student. The students report that in the "Research Physics" framework they would set for themselves goals for learning and make different decisions (such as the choice of the learning contents and degree of depth of learning in these contents) and last they perform supervision and control over their learning. Like the constructivist approach, in which the student is required to be involved and active in the building of the theoretical knowledge and in taking meaningful part in the learning process (Zohar, 2007), the learning in this way takes the student out of his passive position of listener and buyer of knowledge and deploys him in an active process for the creation of new knowledge (Goodnough, 2006; Zohar, 2007), in which the student searches for an answer to a question and in the framework of the search he must use independent thinking (Zohar, 2007). Moreover, the students add and say in the qualitative data that the experience in building knowledge in inquiry that this way increases the students' feeling of self-efficacy in the learning of theoretical material new for him and in his ability to learn it independently also in the future.

The realization of the cognitive apprenticeship approach in the "Research Physics" Program is apparent in the reports of the students on the development in **managing the inquiry work** because of the autonomy they received. First, the students report the meaningful development in the practices of self-regulation in the independent management of their inquiry work. The students report that the inquiry activities cultivated their personal responsibility on the nature of the inquiry and its progress and trained them to have independent ability and initiative. The areas of responsibility and independence are expressed from the beginning of their inquiry work until its end, in terms of the freedom of action in the practical experience (such as organization of the experimental equipment, planning an experiment, and carrying it out independently in the best way), in terms of the ownership of the making of decisions on the directions of development of the project, and in terms of the organization and control of the inquiry work. This ranges from making the time, planning the schedule, and following up after the inquiry and its progress through the

work journal, through the examination of the constellation of the data and ways of performance through critical and reflective thinking and ordering and organization of the inquiry work in an ongoing manner, to the performance of the work. The students noted that they were supported by the mentor-teachers – their support primarily is expressed in the observation and reflection of what is done, shared decisions on what to focus, hints and suggestions of directions of investigation, follow up and formative assessment of the work, encouragement and motivation to advance in the research.

In addition, the students report that carrying out inquiry activities contributed to the development of resilience and flexibility in the coping with the dynamism of the inquiry, with situations of uncertainty, and with frustrations. In the qualitative data the students greatly addressed the complex challenges during the inquiry work, like making decisions, learning from mistakes and failures, coping with situations of powerlessness and uncertainty during the inquiry, with unexpected results (as expected from the inquiry process). Additional confirmation of this finding is that most of the students who participated in the “Research Physics” Program are aware that the dynamism is a part of the development of scientific knowledge (from the inquiry question, through the planning and performance of the experiment, to the conclusions of the investigation) and that coping with it and with mistakes and the search for the solution are opportunities for learning and a natural part of the inquiry process (there is even a significant increase in this position from the intermediate stage to the final stage of the inquiry work). In contrast to the research held in Israel that showed that high school studies do not emphasize sufficiently the temporary nature of science and consequently most of the high school students believe that scientific models and theories are static and immutable (Tamir, 1994), these findings are supported by other research studies in the field of biology, which show that students who engaged mainly in open-ended inquiry are more exposed to possible changes that occur during the performance of the inquiry project and understand how much the inquiry process is dynamic, does not repeat itself, and has a defined direction, sometimes unexpected results are obtained, and it is necessary to change and solve different problems. In the very fact that they are independent to a certain degree, they displayed good control of the inquiry skills and practices and coped better with the dynamism of the inquiry (Berg et al., 2003; Germann et al., 1996; Yen & Huang, 2001; Zion et al., 2004).

Moreover, qualitative data of the present research study revealed that the students who supposedly encountered “failed” experiments in which they obtained unexpected results learned more about the researched phenomenon, opened a way to acquire additional inquiry practices, and developed in creative and critical thinking. “Knowing why the wrong answer is wrong can help secure a deeper and stronger understanding of why the right answer is right” (NRC, 2012). In the present research study, the students report that they used creative thinking and acted with determination and perseverance to create new ideas and solutions, in order to leave situations of uncertainty and solve problems that popped up during the inquiry. Like in the development of scientific knowledge, the scientist uses creativity, acts under conditions of uncertainty, and aspires to be exposed to challenges and opportunities and is determined in his opinion to find for them a solution (Khishfe & Abd-El-Khalick, 2002). The students attribute this to the time and space given to them in the program to deal with these challenges and to search for a solution to the problems, with emotional and moral support and direction as needed by the teacher-mentors (and they do not bring the answer to the challenges immediately, as generally is done in the school). In essence, most of the teacher-mentors were partners in the inquiry along with the students, since they too for the most part did not know the answer to the inquiry questions and they too learned from the successes and “failures” that the inquiry offered.

Another aspect of authentic activity that characterizes the field to which the program directs is research in a team, **teamwork between the student partners and between them and the teacher-mentor**. The students frequently report the work in the research team as a main component that characterizes their work in the program. They report that the teamwork is very different from the teamwork in the school. While in the school laboratory all the students are required to carry out the same tasks, the cooperation with the peers, if there is, is short term (lasting for one or two lessons). Here, in the “Research Physics” environment, many opportunities are provided for teamwork among the students. This is inquiry work that is undertaken in regular pairs for about two years, when each pair of students researches a different physical phenomenon (see the list of projects of the students in the appendix 2.2), in which there is the division of tasks and processes of brainstorming for solving problems. Another important finding that arises from the present research study is the preference for all the students to work in pairs and not alone in the carrying out of the inquiry work for the long term, because of the advantages of teamwork and cooperative learning.

These findings are commensurate with another research study, which determined that those engaging in open inquiry understand the importance of cooperation with their peers on the team (Yen & Huang, 2001). In the qualitative data of the present research study, the students brought up the importance and advantages of the teamwork between them and their project peers: the reciprocal fertilization in the understanding of the theory and investigation ways (clarification of principles, sharing of concepts and ideas in discourse), brainstorming for solving problems and developing ideas, division of the work between the team members in order to increase efficiency and progress in the inquiry, and complementation of one another – each one contributed to the performance of the project the part in which he is better. In addition, the students learned from the teamwork about themselves that they can learn in cooperative learning with the project partner (which was not obvious to them) and that they improved their ability of teamwork and their social skills necessary for this, such as willingness to compromise, patience, attention, accepting criticism, reciprocal respect, and inclusion ability, support and reinforcement of the partner. No less important, they exhibited enjoyment of the activity together and the relations of friendship created between them. Like many research studies that showed that the performance of an inquiry project together for the long term, the students discussed the relevant knowledge and the skills required for the project, through the constant need for cooperation between the team members, and peer learning advances inquiry skills and has impact and meaning on the building of knowledge. Conversations and discussion in the peer group enable the clarification of things and the sharing of information and ideas and help to understand the knowledge, increase the students' motivation and critical thinking, the listening to partners, and the acquisition of social and emotional skills (Khishfe & Abd-El-Khalick, 2002; Hofstein et al., 2004; Wu & Hsieh, 2004; Akerson, 2007; Sowell et al., 2007). Students who work in groups ask one another questions that contribute to the identification of defects in the planning and in the performance of the inquiry task and questions that advance the learning and the investigation, and the discussions give rise to new ideas and solutions, from which there may grow insights that help the improvement of the inquiry constellation (NRC, 2005). In addition, a dialogue that was held between the group members in the project caused the raising of ideas and suggestions for change and for the performance among groups as opposed to individual students (Hmelo-Silver, 2004).

The students' perception of the interaction in the research staff – between the partners and the teacher-mentor in an environment that focuses on inquiry. In the students' eyes, the program teacher-mentors need to find the balance in the degree of their involvement in the inquiry process that will allow on the one hand time and space of action for the students to perform the inquiry work and to manage it independently and on the other hand support and planning direction when necessary, when an equal status is given between the teacher-mentor and the student to resolve lack of agreements on different aspects in the project and the student's desire has a decisive importance in making decisions on the directions of development of the project and the ways of investigation. On the one hand, it is necessary to set for the students questions and challenges that require critical and creative thinking, and on the other hand, it is necessary to provide contexts and to constitute a source (but not exclusive one) for information, when the students do not have the ability to answer by themselves.

In addition, the students brought up the importance of creating relations of trust and openness on the part of the teacher-mentor with the students and of giving them a personal relationship and empathy. The research findings (see chapter 4, section 4.3) indicate that a vast majority of students who participated in the "Research Physics" program expressed satisfaction with the cooperation between them and their teacher-mentor for different reasons: experience and knowledge of all the entire instructional staff (teacher-mentors, academic counselors, and laboratory assistants), openness, and trust created between them and the instruction staff, availability and responsiveness of the teacher-mentors to questions, display of empathy to the students who encountered difficulties during the inquiry, mainly from the support of the teacher-mentors so that there was no harm to their sense of independence in the management and leadership of the inquiry. However, there are still students, albeit a few, who expressed lack of satisfaction with the teamwork with their teacher-mentor. From the qualitative analysis, it is possible to see that both the students' satisfaction and lack of satisfaction address the same factors mentioned above. Like the research findings of Zion et al. (2007) in the group of students who engage in inquiry in the field of biology in Israel, there too low percentages of students expressed emotional difficulties of a feeling that they do not rely on the teacher and his guidance.

From the students' descriptions of the development aspects in the different inquiry components and their ways of coping (see chapter 3, section 3.2 – a detailed description of the aspects of development of the students in the inquiry components examined in the different inquiry stage), it is possible to learn that inquiry activities will lead to meaningful development when the student is more involved and independent in their performance, when he is allowed to cope with the challenges entailed by the different inquiry components. The students reported that they used initiative and creative and critical thinking and took responsibility and ownership of the work in order to overcome challenges that the inquiry offers (see chapter 3, section 3.1 – a detailed description of the challenges of the students in all the inquiry components examined in the different inquiry stages and ways of coping with difficulties). In parallel, the teacher-mentors on the one hand pushed the student to go into-depth and on the other hand gave the student a safety net for coping with the difficulties, without harming the student's independence. This approach is also commensurate with the recommendations written in the review of the literature: the teacher needs to be involved in the complex processes his students are going through, to help them navigate their way from the moment a problem came up, and until a satisfying and sound solution is found for it (Chinn & Malhotra, 2002).

The teacher needs to aspire to reduce the student's dependence on the answers ready ahead of time. He needs, from time to time, to release his students from the need to absorb and assimilate frequent theories, and to enable them a personal space to move freely in a sea of information, to think by themselves, to ask questions, to research, to assess what they know, to consider and make decisions, to reach conclusions, and to form a way to present the new knowledge in a convincing manner (Anderson, 2002; Goodnough, 2006; Zohar, 2007). In addition, the teacher-mentor must encourage the student take responsibility for his learning, simultaneously provide an answer to the problems that the students cannot answer by themselves, and give the students moral, social, and cognitive support. The teacher is found always in the background, to navigate and to direct towards the goal, and preserves the level of challenge and reward of the motivation at all times (Chin & Chia, 2004).

Further reinforcement of the realization of the approach of cognitive apprenticeship, which is anchored in the performance of an authentic task, is the students' report of **identification with the scientist's world**, when the research experience as performed advanced their knowledge and understanding of the nature of scientific research and especially the character of the process of research in physics. The students noted that the "Research Physics" environment is an environment similar to the world of the scientific researcher: in terms of the learning resources and means that enable to perform a broad inquiry – both in terms of an abundance of equipment, modern and sophisticated equipment, meaningful time for the performance of inquiry, and an instruction staff (teacher-mentors, academic counselors, and laboratory assistants) and in terms of the work as a scientist and the internalization of the inquiry process. The students reported that they learned methods of researching scientific questions and development in different levels of inquiry practice, like the scientist. In particular, the students addressed the practices of choosing a topic, phrasing questions, making decisions about the focusing of the questions and the way they are examined, and planning and performing an experiment. The students proposed many proposals for the improvement of the experiment reliability, reached stages of processing and analysis of the data, performed a comparison between theory and findings of the experiment that led to the writing of the conclusions, and last presented in writing and orally the inquiry work in general. In addition, in the performance of the inquiry projects in the "Research Physics" program the students coped with the changes and with the unexpected results during the inquiry and with the coping with solving problems and finding an answer to a question after a continuous search. These copings are a natural part in the inquiry process, and through them it is possible to understand the nature of the inquiry. In the research findings (quantitative and qualitative) the students voiced expressions of identification with the scientist's world and said explicitly that the performance of the inquiry strengthened their knowledge and understanding about the nature of the inquiry process. These statements are expressed also in other research studies. Students who were more active in the planning of the experiments and who used the knowledge and skills they acquired internalized the meaning of the inquiry process and science as a whole (Barrow, 2006; Roberts, 2001; Yerrick, 2000). Barrow (2006, p. 269) wrote that: "when students practice inquiry, it helps them develop their critical thinking abilities and scientific reasoning, while developing a deeper understanding of science".

The implications of the cognitive apprenticeship approach led to the **positive change in the students' perception of their self-efficacy** and increased their curiosity and interest in engaging in science and inquiry in the future. The quantitative findings of this research study note an important indicator of practices that the students believe they have acquired, their experience that they can cope with another new inquiry project relatively easily. The change in their perception of their self-efficacy also arises in the qualitative data, expressed in the reduction of the fear about coping with new things or “failures” (in the student’s eyes) and their belief in themselves and that they can perform inquiry work and deal with the difficulties that the inquiry poses. Another research study found that after the students had the inquiry experience and used the knowledge and skills they acquired, this reinforces their self-confidence in performing inquiry (Yerrick, 2000). In addition, the students note that the inquiry activities in the program enabled familiarity with the world of the scientific researcher and they felt that they perform the work of a scientist-researcher, and this experience increased their curiosity to choose a future career related to science and research. This finding was found to contradict the findings of another research, which reviewed a wide range of school inquiry activities and found that most of the activities do not reflect well the epistemology of an authentic scientific research (Chinn & Malhotra, 2002) and another research that shows that many students hold negative stereotypes related to science/scientists, who are distant from the perception of an authentic scientific research. This negatively influences their attitudes towards science, the choice of scientific trends, and future choice of professions related to science (Osborne et al., 2003; Scherz & Oren, 2006).

In addition, added value to the learning through inquiry is the increase of the chance among the students to develop positive attitudes towards science and a number of research studies indicated the positive relationship between an authentic experience of the students in the research laboratories and their attitudes towards science (Gibson & Chase, 2002; Ogens, 1991), or namely, attitudes that reflect the epistemology of an authentic scientific research. According to these researches, the students’ attitude in the present research study were found for the most part to be positive already in the intermediate stage (eleventh grade) and in the final stage of the inquiry work (twelfth grade) towards the inquiry process in the “Research Physics” learning environment and towards

the contribution of the program to their ability to perform the inquiry work and their personal growth (see the findings in chapter 4, section 4.2). In addition, another research study indicates that the students' attitudes depend on the students' degree of involvement and active participation in the learning, so that as the students are more involved and independent in their inquiry, they will develop attitudes towards science that are more positive (Ornstein, 2006). These findings are supported by my research study, since in the view of the observation and from the reports of the students, the students who participated in the "Research Physics" Program were very active in their inquiry work and in the building of content knowledge relevant to the inquiry and engaged in authentic problems they chose and were interested in (from a selection of topics), and over time the students were more independent in the performance of the inquiry and they coped with the dynamism in the process of inquiry that includes unexpected results and changes according to the development of the inquiry. According to the research studies, indeed in the present research study the students expressed positive attitudes towards the inquiry process that reflect the perception of authentic scientific research. Therefore, it is possible to say that the present research study strengthens the argument and shows that active experience in activities of inquiry in science (in the research field the students engaged in particular in physical phenomena) that address authentic problems that interest the students helps cultivate positive attitudes among students that reflect interest and appreciation of the scientific research method and learning through inquiry (primarily about the roles of the student and the teacher and learning resources given to them in this approach).

Now, after we have seen that the student participates in authentic activity that characterizes the field, semi-structured open-ended inquiry, and the main principles of design of the program, there is room to examine the students' personal development in its framework: what are the reciprocal relations between the experience, challenge, and development of the students in the different inquiry practices. The present research study found four groups of inquiry components, which are different in the track that describes the relationship between development, experience, and challenge during the inquiry work in the "Research Physics" Program (see chapter 3, section 3.4). In two of them, there was meaningful development among the students in the carrying out of the inquiry components, and in the other two groups of the inquiry components the development was sparse among the students.

The two groups of inquiry components in which many students report meaningful development: Group 1: phrasing questions/goals, drawing conclusions, and building content knowledge and Group 2: choosing a topic, performing an experiment, self-regulation, teamwork with the partner, and written reporting on the inquiry (for description of the aspects of development in these inquiry components in all the inquiry stages (see chapter 3, section 3.2). In these two groups, the meaningful development among the students is commensurate with a considerable degree of experience, while coping with components in the first group was perceived by the students as especially challenging and in the second group was perceived as less challenging (description of experience and challenges of the students in these inquiry components see chapter 3, section 3.1). The coping with the challenges in the performance of these components based on the one hand and developed on the other hand character traits of curiosity, desire to succeed, perseverance, responsibility, openness, and ability to learn together with the project partner. In these components considerable support is required (practical and mental) of the teacher-mentors and academic counselors. On the one hand, there is need for support of entertaining thinking – critical examination of the intermediate products, which extends the reference to a range of aspects in the researched phenomenon. On the other hand, there is need for focused help – identification of the information sources relevant to the researched topic, explanation of things that are not understood or are complicated for students, providing suggestions for students for directions of investigation and ways of performing investigation, as long as the students' independence is not harmed.

According to these findings, the recommendation of the research study is to preserve the structure of the program existing in these two groups, when there was considerable experience in most of the inquiry stages and to increase it in the case that it existed only in the final stage (see the description of the recommendation for every component in chapter 3, section 3.4). In particular, it is desired to perform the inquiry project in set pairs from the beginning to the end, to let students use judgment independently in the choice of the inquiry topic, to give them freedom to change the inquiry question accordingly and to focus it to the development of the inquiry, to begin with simple exploratory experiments at the beginning and continuing with coping with building a more complex and sophisticated experiment system according to the investigation directions, to

enable coping with the gap between the experiment results and the theory, and in the search for an explanation for this, and to enable students to learn and build the content knowledge independently during the practical experience in the laboratory. In addition, it is desired throughout the entire inquiry process to increase the students' awareness of the importance of planning and organizing the inquiry work, planning correctly the schedule (including the division of the work between the partners), documenting the inquiry in a continuous manner from the beginning of the inquiry through a inquiry journal (that includes the entire inquiry process and its products), and performing control over what is done during the inquiry work.

However, not in all inquiry components examined in the present research study did the students indicate meaningful development. The two groups of the inquiry components in which few students report meaningful development (whether there experience was considerable or limited): Group 3: identifying sources of information, using technological aids and a computerized laboratory, building a theoretical model, and teamwork with the rest of the peers / Group 4: planning an experiment, processing data, and oral reporting on the inquiry.

In the group of inquiry components of group 3 – few students reported meaningful development in them during the program following a low degree of experience and challenge in these components. As expected, poor experience did not lead to meaningful development. The research recommendation is to add activities directed at further experience in these components during all the inquiry stages in order to improve the students' performances in these inquiry components (see description of the recommendations for every component in chapter 3, section 3.4). In particular, to increase the students' awareness of the importance and effectiveness of building a theoretical model through computational modeling, which enables to reach an in-depth inquiry and deeper understanding of the concepts and principles relevant to the researched phenomenon. In addition, it is important to increase activities that include peer assessment, which is another source for students to receive constructive criticism and direction for the improvement of the inquiry work and encourages the performance of follow up and control over their work. The goal of peer assessment is to ask critical questions, to provide feedback for peers, to identify mistakes, to make suggestions for improvement, and to allow the student to deploy strategies for correction as necessary (Birenboim, 2009; Biton, 2011; Krajcik et al., 2001).

Group 4 is exceptional since it deviates from the research assumption and was not realized according to it (the research assumption was that the degree of experience or degree of challenge that the students experience in the inquiry components in the program would influence the degree of development of students in those components). In this group there are inquiry components in which the students' development was sparse, although the students experienced considerably these components during most of the stages of the program. Hence, it is possible to understand that it is not possible to rely on the considerable degree of experience given in the learning environment that focuses on inquiry but it becomes clear that some of the inquiry practices do not develop spontaneously with the experience among most of the students.

Indeed, in accordance with the structure of the program and the observation (see chapter 3, section 3.3), there was considerable experience in most of the stages of inquiry in the three inquiry components of Group 4 (planning the experiment, data processing, and oral reporting of the inquiry). Already in the stage of preparation, the students were exposed to different instruments for processing data and implemented them in the continuation. The inquiry project obligated repeated engagement in the planning of the experiment, and the program incorporated an oral presentation in the advanced stages of the inquiry. However, the program did not explicitly engage in tools for planning, and feedback on the planning was held according to the opinion of each teacher-mentor, without common templates, when some of the teachers even propose planning solutions for the students. Regarding the component of data processing, the program did not obligate use of advanced statistical analysis tools (beyond the standard ones they were first exposed to at the start of the program). Like with the topic of planning, the program did not engage explicitly with tools for oral presentation, and the support by the teacher-mentors towards the oral presentation was according to the opinion of each and every teacher-mentor.

The present research study indicates that from the students' perspective the situation without the building in these inquiry components was not beneficial for them. What is prominent is that the students report considerable experience without meaningful development for these components that the program chose not to structure (from the observations, see chapter 3 section 3.3). The question that the literature deliberates – to structure or not to structure – and there are advantages and disadvantages of the different

levels of inquiry found on scale between structured inquiry and open inquiry (Brown et al., 2006; Domin, 1999; Martin-Hansen, 2002; Hofstein & Lunetta, 2004; Trautmann & MaKinster, 2005; Trautmann et al., 2002; Windschitl, 2003; Zohar, 2007) and the extent to which the teacher guides the student during the inquiry, the choice to structure or not to structure derives frequently from personal reasons of the teacher-mentors and the program developers.

The implications of these findings obligate re-examination of the way in which the program was built in the inquiry components of Group 4 (planning an experiment, data processing, and oral reporting on the inquiry). The recommendation of the research is to change and to improve the existing structure of the program and emphases of the instruction in the components of this group in order to provide instruments for students through which students can develop in these components and not only on the basis of the degree of considerable experience provided in the program (see the description of the recommendations for every component in chapter 3, section 3.4). In particular, to enable the students to carry out the component of planning an experiment independently already in the early stages of the inquiry and in parallel to examine the initial planning of the students and to provide for them feedback that will also include suggestions for improvement, to challenge the students in the component of data processing beyond the standard ones to which they were exposed in the school setting and use of more advanced statistical analyses (such as the dispersion of the findings and evaluation of the uncertainty in the measurements) alongside the teacher-mentor's support of this. It is desired to give more reference and support to challenges that the students face in the component of oral reporting of the inquiry, including emotional challenges and providing time and framework for implementation of the feedback given after the presentation.

As described in the research study (see chapter 4, section 4.1), it is possible to see that there are also great gaps, quantitative and qualitative, between two cultures – between a laboratory culture in the school and a laboratory culture more similar to the scientist's laboratory (for instance, "Research Physics"). The students reported a considerable gap between the learning goals to which they were accustomed in the studies of physics in the school and the goals required by them in the research physics program. According to the research that focused on the transition between the stage of experience before the stage of the research project (Perl, 2019), we distinguish between a quantitative or qualitative gap in the

perception of the students of the different components in the inquiry. A quantitative gap in the perception of a certain inquiry component focuses on the difference in the scope – the student is required to do a lot of the same inquiry component. A qualitative gap in the perception of a certain inquiry component addresses a situation in which the same inquiry component has essentially different meaning between the school laboratory and research physics.

The following question is asked. If in Group 4 (in which the development was not commensurate with the experience, the development is sparse despite the considerable experience), there were qualitative gaps and not only quantitative ones, why is the difference considerable compared to Groups 1, 2 (in which the development is commensurate with the experience, meaningful development is commensurate with considerable development)? **A possible explanation of this question is the difference in the scaffolding given to the students in the performance of the inquiry components during the program.** The findings of the present research focus on the importance of the scaffolding of the cognitive apprenticeship and building the relationship between the development and the experience in the different inquiry components examined in the research study (in which the difference is not only quantitative but also qualitative), **so that the development is commensurate with experience according to the scaffolding provided.**

The cognitive apprenticeship theory addresses the support of qualitative gaps and emphasizes that the support of the qualitative gap obligates scaffolding that externalizes the nature of the knowledge and the practices of authentic research that are different between the expert and the novice. The expert provides scaffolding through coaching students' decision making within structured frameworks, modeling, and externalizing experts' problem solving strategies, and in the continuation fading – removing the scaffolding gradually (Collins et al., 1991). From the students' reports and the view of the observation (chapter 3, section 3.3), in the program scaffolding was provided for the inquiry components of Group 4 (oral reporting on the inquiry – towards the end of the eleventh grade and towards the end of the twelfth grade, in the planning of the experiment – in the milestones of the intention document 1 and intermediate report (see appendices 2.3, 2.4), in the component of data processing – the support was not orderly). However, these scaffoldings were very distant from one another and did not necessarily externalize the nature of the different knowledge of the expert relative to the novice. It is reasonable that these scaffoldings were

not enough to lead to significant development in these components despite the considerable experience of the students in these components during the entire program. In contrast, in the inquiry components of groups 1, 2 there was continuous and frequent handling of the interaction between the teacher-mentor and students according to the principles of cognitive apprenticeship (described above), when with time the teacher-mentor gradually reduced the student's dependence on him and the student's independence grew in the performance of these components. In addition, another interesting finding obtained from the qualitative analyses (see chapter 4, section 4.1) (which reinforces the argument that the scaffolding provided did not externalize the practices of authentic research in the inquiry components in which the students report little development) is that many students identified qualitative gaps between the performance of laboratory activity in the school and the performance of inquiry activity in the "Research Physics" framework in inquiry components in which they had meaningful development (Groups 1, 2) and very few students identified these gaps in the inquiry components in which there was sparse development (Groups 3, 4) and although in some of them they reported considerable experience (Group 4).

The above analysis has implications on the design of the program and the support of the teacher-mentors in the different inquiry components and especially in components in which the students report development that is not commensurate with the experience. Hence, the teacher-mentors' support in these components was necessary, and the program had to build scaffolding like is done in the inquiry components in which the students reported meaningful development according to the principles of cognitive apprenticeship (modeling, coaching, fading). In particular, these scaffoldings need to follow the proposal (Akkerman & Bakker, 2011) for support in the transition of the boundary between two cultures that have between them a considerable gap, as in the example of the laboratory culture in the school and scientist's laboratory culture (for instance, "Research Physics"), in that they bring to the student's awareness the differences between the two cultures and explicitly externalize the norms and practices of authentic research.

Another research (Walkington & Rushton, 2019) reinforces the argument of the present research and suggests prominent practices of cognitive apprenticeship activity in high school framework for teachers that are similar to the proposals of the present research study. In particular, the role of the teacher-mentor is to provide personally tailored direction

and counseling, to address the students' changing needs at different points in the process, and to provide strong support in an early stage of the inquiry. In addition, the teacher-mentor should give the students independence in a gradual fashion and increase the students' ownership of the research study over time. Alongside this, the teacher-mentor should listen patiently and openly to the students, build relations of trust in the team, and remain accessible so as to minimize anxiety and increase the students' confidence in the ability to carry out inquiry work. This approach is based on the social constructivist approach to learning, in which the students are supported by their peers, their teachers, and other collaborators, in order to develop their understanding of the science (Rushton & Reiss, 2019).

To summarize, research studies in Israel and in different places in the world attempt to find ways of instructing inquiry that will increase the understanding of the nature of science among teachers and students (Barrow, 2006; Hofstein et al., 2007; Kapach, 2014; Krajcik et al., 2000; Langley & Alon, 2007; Roberts, 2001; Sadeh & Zion, 2009; Zion et al., 2007; Zohar, 2007). At the start of the 21st century, we are in the midst of a reform in teaching science in the world. The contents and ways of learning and teaching sciences are being reviewed, and new standards are being set for shaping education and science. These standards reaffirm the approach that holds that inquiry is a main part on the way to achieve the goals of the teaching of sciences (NRC, 1996, 2000). The present research study showed that **the complete and long term process of inquiry** is meaningful and facilitates the internalization of different practices acquired in the performance of the inquiry project. The students described the development aspects in the different inquiry components throughout all the stages of the program, and the students indicated the advantages of the learning through inquiry and its contribution to their personal growth. The research findings indicate that the graduates of the "Research Physics" program had true research experience and had a meaningful experience of learning through inquiry at a variety of levels of inquiry (from structured research to open-ended research). The students performed an entire process of scientific inquiry and developed different inquiry practices: from the search and choice of the phenomenon, the definition of the problem/question, the search for ways of solution through planning experiments and performing them, analysis of the array of the data until the drawing of conclusions, and presentation of the research in the forum, including dealing with the challenges that accompany every inquiry process.

The present research also indicates that the performance of inquiry activities enables the students to develop their thinking and learning skills and enables them to build new knowledge independently and to search continuously for an answer while using critical thinking, to develop skills of teamwork, to encourage natural curiosity, and to provide an outlet for creativity, in order to find solutions for different problems that arose during the investigation, to promote their ability to act under conditions of uncertainty and to adjust to changes that occur in the work process. These are in essence the needs for coping with the challenges of the 21st century and practices necessary for the integration in advanced society (NGSS, 2013; NRC, 1996; Salomon, 2000). These findings are supported by additional research studies. There is no dispute about the great necessity for learning through inquiry to the development of a scientifically literate citizen, who can think critically, logically, and creatively (Sadeh & Zion, 2009). It was found that in tests that examine inquiry skills there is a chance that a greater difference will be found after a long term inquiry program than short term inquiry activities and that the acquisition and internalization of inquiry skills takes time (Harlen, 2004; Khishfe & Abd-El-Khalick, 2002; Staer et al., 1998; Zion et al., 2007).

However, as described above, the students did not develop meaningfully in all the inquiry components (although in some of them the students experienced considerably, components Group 4). The explanation given is the difference in the scaffolding provided to the students in the performance of the inquiry components during the program. The present research study raises the importance of the scaffolding of cognitive apprenticeship to the building of the relationship between the development and experience and challenge in the performance of the inquiry components, since it was found that the development is commensurate with the experience according to the scaffolding provided. particularly when there are large gaps, quantitative and qualitative, between two cultures – between the laboratory culture in the school and the laboratory culture more similar to the scientist's laboratory (for instance, 'research physics').

To help the students develop practices required for the performance of the inquiry and abilities of solving their problems, on the one hand it is necessary to enable the students to carry out tasks that are not trivial for them and constitute an opportunity to phrase a problem, to propose a method of problem solving, to overcome “obstacles” during the search for a solution, and to examine the result of the problem solving. On the other hand,

it is necessary to perform scaffolding activities structuring and problematizing (as described above and at length in the review of the literature chapter 1, section 1.3.4.2), which help build the task of problem solving (Reiser, 2004). When the teacher reduces gradually his support and increases the levels of freedom, empowers the students and directs them to continue independently, he thus enables the students to cultivate their self-autonomy and solve problems independently (Collins, Brown, & Newman, 1989). In addition, it is necessary to ask guiding questions, to direct the students' attention to actions that they are not aware of, and to provide feedback on the students' work orally and in writing that includes formative assessment throughout the inquiry process. This is to provide the student with information about his learning and to enable him to deploy strategies for correction as necessary, as well as to think about the following steps in the investigation and to follow up after the learning process he undergoes (Birenboim, 1997; Harlen, 2003). These scaffoldings can help students cope with the challenges they face during the inquiry work, support the students' learning, and shape the students' performances and understanding of the inquiry.

Hence, in order to find ways of teaching/learning in the way of inquiry that will increase the understanding of the nature of science among teachers and students, it is necessary to allow in the education system the students and teachers a laboratory culture similar more to the scientist's laboratory, for instance, "Research Physics", which constitutes an example in some of its design principles. This environment will promote inquiry that engages in authentic problems in a continuous manner and for the long term, for at least a year and a half (and not for the short term). This will enable the students and the teachers to perform a whole and meaningful inquiry project, both in terms of the content of the inquiry work (to go in-depth in the content and to make it into meaningful knowledge) and in terms of the way of performance of the inquiry (to go in-depth in the different inquiry practices and the understanding of the nature of the scientific inquiry process). To internalize the nature of the inquiry and its components, it is necessary to expose the students to changes that occur in the inquiry process and the dynamism in it, to set for the students objectives, and to increase gradually the standards required in the performance of the different inquiry components and to adjust the interventions and supports of the teacher-mentors who will help the student reach the required objectives (which suit the principles of cognitive apprenticeship as explained above).

A learning process in this way enables the understanding of the researched scientific phenomenon, the understanding of the nature of science and the inquiry process, and the making of the student into an independent researcher with initiative. In light of the findings of the present research study, in a research physics environment, similar to the scientist's environment, there is the potential to advance the students' learning, to help them develop in an optimal manner in different inquiry practices, and to understand the inquiry process itself. Therefore, appropriate place should be given in the constellation of education in the world in general and in Israel in particular to learning environments that offer the students an opportunity to experience authentic inquiry with a modern research laboratory and equipment and that encourage the integration of inquiry in science in general and in teaching physics in the high school in particular.

The encouragement of the performance of inquiry projects open for students obligates the training of teachers in parallel. The improvement of the teachers' teaching of inquiry will contribute to the improvement of the students' degree of inquiry (Sadeh & Zion, 2009). The main factor, which influences the teacher's intention and ability to teach science as inquiry, is the teacher's personal outlook regarding pedagogical aspects of the inquiry process (Crawford, 2007). The absence of the teachers' experience in true scientific inquiry creates in them a static perception of the science, which is not subject to changes, doubts, and criticism (for instance, in their perspective an experiment is supposed to provide a clear and immediate answer in order to confirm the theory learned in the classroom), and generally causes difficulties in the use of teaching through inquiry in their classes (Kapach, 2014; Windschitl; 2003). In addition, for the teachers it is challenging to perform preliminary planning of an authentic research, when there is lack of knowledge with the specific research field and a true sense of "striding towards the unknown" with the students, since the research project broadens to regions beyond the curriculum (Walkington & Rushton, 2019).

Despite the difficulties in teaching open inquiry, teachers around the world are interested in programs that integrate open inquiry in the class (Trautmann & MaKinster, 2005), as well as in Israel (Kapach, 2014; Zion et al., 2007). Little attention was still dedicated to the roles and practices of teachers who engage in the school-based scientific research (Rushton & Reiss, 2019), and there is a lack of content and process knowledge of

the teachers of the inquiry process. This lack obligates a system of support for teachers for the long term and training courses for professional development on this issue (Kapach, 2014). It is necessary to help the teachers of the scientists to understand that science is a field of knowledge that emphasizes uncertainty, dynamism, innovation, human deliberation, teamwork, and meta-cognitive thinking, which are natural processes of the scientific inquiry, as a preparation for the modern lifestyle that is characterized by these components (Kapach, 2014; Zion et al., 2007). For this field, the present research study contributes and provides suggestions for teachers in in guiding students in performing the various inquiry components, informing future improvements for the design of this program and similar ones. Hence, the results of the research can be useful in the search for effective teaching methods to advance the subject of inquiry in teaching science. In addition, the research study reveals the students' positive attitudes towards the inquiry process regarding the role of the teacher and the student, their satisfaction with the guidance and with the learning resources that are given during the performance of the inquiry, and also the feeling of the students about the contribution they received from the performances of the inquiry project (their development in the ability of the performance of the different inquiry practices and their personal growth). This exposure of the present research findings may make it easier for the science teachers to choose to engage in inquiry with their students and to provide opportunities for students to work on real problems in order to develop an approach for school education in which inquiry is a main component in the learning.

5.2 Research Limitations

The research study has a number of limitations:

The first research limitation pertains to the research population – the students of the “Research Physics” Program of the regional class, (second class, the program period 2016-2019), from five schools, which was held in the Davidson Institute of the Weizmann Institute, Israel. It would seem that in a research the students must “be identical” in order to ascertain that only the inquiry experience is different in the other variables. Of course, in essence it is difficult to control variables such as the students’ background (sex, ethnic origin, residence), the students’ traits (such as perfectionism, mental resilience, orderly, intellectual thinking capacity, creative thinking ability, and so on), and the student’s

attitude towards science and inquiry in particular. However, an effort was made for the composition of the population to be as similar as possible. These are high school students who study in parallel five units of study in physics (22 boys and 12 girls), with learning motivation, ability, and interest (according to their teachers' recommendation). None of them had experience in inquiry before the program. In addition, one of the ways to avoid this difficulty is to use the group as a control for itself, to measure the changes before the intervention and after the intervention (Harlen, 2004). Therefore, in the present research study there is no control group but the group itself poses control of itself. The research is a development research (over the course of three years of study of the students in the program) and focuses on the students' perceptions of their experience, challenge, and development in the different inquiry components in different stages of their inquiry work (preparation stage, intermediate stage, and final stage of the inquiry work). Comparisons were held between the different stages. In addition, there was follow up after their perception of the environment that focuses on inquiry (the roles of the student and the teacher, the learning characteristics, the learning and support resources that in their opinion they received in the framework of the program and their satisfaction with them), throughout the main milestones during their inquiry work, through questionnaires, interviews, and observations.

Another limitation pertaining to the research population is the number of students in the research – 34 students. Therefore, the research tendency, in the quantitative part, is deductive. The research concluded from all the respondents about the single person (although the number of respondents is small relative to what is accepted in quantitative research). The research tendency in the qualitative part is inductive, and the research follows up after the students' perception for a relatively small number of respondents and from this creates insights on the entire population they represent (assuming that it is possible to generalize in some way about the entirety of the population). The qualitative data served to elaborate, enhance, illustrate, and clarify the results from the quantitative method and thus added validity and legitimacy to the research conclusions because of the small number of research participants.

Another research limitation derived from constraints pertaining to the teachers who participated in the instruction of the students. A teacher-mentor was assigned to every pair

of students. There is difference between the teacher-mentors, in terms of their knowledge and expertise on the inquiry topic, in terms of their perception of the inquiry, and in terms of their perception of the way in which it is necessary to instruct inquiry for the students. The teacher's personality, background, and outlook have impact on the students' way of learning during the inquiry (Crawford, 2007). In addition, other teachers may influence the student's learning and perception of the inquiry, and not only the influence of the direct teacher, and these are factors over which there is no control (Harlen, 2004). Alongside this, in the "Research Physics" program an effort was made for the teachers who instruct the students to receive the same training in the framework of an "inquiry core" (of the Davidson Institute), in which they received identical instruments how to instruct the students in inquiry work in each and every stage and how to support them.

Third, the research approach was based mainly on the students' self-reports (questionnaires and interviews), and tests were not held to verify the correctness of the students' words. To overcome this difficulty, observations of the students were held during the program sessions and over their products, to perform control of the students' statements. The observations were held once every two weeks for the first year of the program (when the students were in the tenth grade) and every week in the last two years of the program (when the students were in the eleventh grade and twelfth grade). Every session lasted three hours. For the most part the students' reports were commensurate with the observation, and the cases in which there was no correspondence were noted (see chapter 3, section 3.3).

Fourth, another research limitation addresses the research instruments. The present research study used mixed methods research (questionnaires, interviews, and observations), which combine elements of the qualitative and quantitative research approaches (Johnson, Onwuegbuzie, & Turner, 2007). The integration of the quantitative and qualitative approaches delineates a richer picture of the discussed phenomenon, an in-depth and broad look at the field (Sabar Ben-Yehoshua, 1990). Moreover, each one of the methods, qualitative and quantitative, has limits and biases, and therefore the use of more than one method may neutralize or overcome the biases of another method and thus contribute to the validation of the findings (Axinn & Pearce, 2006; Tashakkori & Teddlie, 2003).

One of the fears of holding interviews was the harm to the internal validity. In the interviews, the interviewer's influence is possible, in his responses to the interviewee's answers (Patton, 1990). Conversely, an attempt to avoid the involvement through the adoption of an exaggerated neutral position may lead to disconnection, indifference, and even hostility (Sabar Ben-Yehoshua, 1999). In addition, in the very existence of the interview itself there is the (natural) concern of some of the interviewees to express themselves freely, in all that is related to topics related directly and indirectly to their inquiry project. They are concerned that their responses will be conveyed to other factors (such as to their teacher-mentors, to the program developers) and may influence their grades and/or the attitude received from them after the interview from the interviewer. Therefore, in parallel to the concerns, it is necessary to develop relations of trust with the interviewees (Shkedi, 2003), and non-formal sessions may increase the trust, with the goal of knowing the students even before the interview (Sabar Ben-Yehoshua, 1999). Therefore, I (the researcher) joined most of the program sessions, observed the students, formed relations of trust, was interested in their inquiry projects, and even helped them as necessary. In addition, to create a more intimate atmosphere and a system of trust, the students received an explanation why the interviews are necessary for the research, and I asked for their permission to write down and record their words. It should be noted that not all of the interviews were recorded, according to the student's choice, despite the great importance of the recording of the interviews (Shkedi, 2003).

In all the interviews, the interviewees were promised anonymity and confidentiality, and an effort was made to carry out a neutral investigation, without judgment, to receive full cooperation from them. We note that in this research study the students cooperated willingly and the atmosphere in all the interviews was pleasant and relaxed. In addition, the interviews were semi-structured (Sabar Ben-Yehoshua, 2001; Shkedi, 2003), when the main questions were phrased ahead of time, but the continuum of their presentation is not determined ahead of time and there is room during the interview to add questions according to the context, when sometimes the interviewee's answers lead to spontaneous questions. The questions prepared ahead of time constituted in essence a formal interview, which sometimes is necessary in order to ensure the uniformity of the interview topics (Sabar Ben-Yehoshua, 2001; Shkedi, 2003), also for the involvement to be as identical as possible and the influence of the interviews, if there is, to be similar with all the students who were interviewed.

Similarly, in observations the researcher himself will decide how much he is interested in being a partner in the occurrence, and his degree of participation can influence the research participants' behavior (Beyt-Marom & Ashkenazi, 2012). In the present research study, for the most part the observations were open-ended observations, with observation and notation of the events and behaviors in the researched environment, without the planning ahead of time of what is observed. All this, in order to document all the observed behaviors as they occur in their natural environment. The advantage in this type of observation is description of the behavior in a true situation. The disadvantage is that the observation does not explain why a certain behavior appears (Beyt-Marom & Ashkenazi, 2012). Some of the observation performed in the research study were "non-participative observations" (Beyt-Marom & Ashkenazi, 2012), in which I participated actively during the sessions with the students, as an overt or covert observer. The level of participation was moderate and through a lengthy stay (throughout all three years of the students' studies). The goal was to accumulate experience and knowledge – to understand the researched experience, the language and the culture from his viewpoint and in his natural environment. The difficulty with performing this type of observation that the researcher needs to observe and see what the respondents are doing and concurrently must participate in what is done in the research environment. The challenges in this type of observation are the creation of an initial relationship with the respondents, a possible approach for the researcher to be involved in the research respondents' life, ability of objective observation, representation and unique ethical issues (Beyt-Marom & Ashkenazi, 2012).

Sometimes the observations are overt observations, in which the students are aware of the fact that they are being observed. The disadvantage in overt observation is that they cause the respondents to behave differently and how they need to be perceived and not how they are in actuality (Beyt-Marom & Ashkenazi, 2012). However, since I alternatively was a participative observer, for the most part we see that the students forgot that they are being observed. The present research study, while observing, attempted to maintain observation and listening to the participants in their natural environment, to understand how they interpret the world, and to write texts that are close to the participants' experience. However, the research study attempted to research in as neutral a manner as possible.

5.3 Suggestions for Further Research

This research study proposes additional directions for future research studies that derive from the findings of the present research and from its limitations. When the results presented in a research are limited to a number of students, there is always a chance that the results will not represent the phenomenon in the entire population. Therefore, another research study should be performed, with another sample, so that it will be possible to wholeheartedly generalize the research results (Khishfe & Abd-El-Khalick, 2002). In addition, the present research population did not include students who performed the inquiry projects in the school (the present research field was in the regional class of the Davidson Institute of the Weizmann Institute, which students from the region attended). In addition, a comparison was not performed in the students' gender. High school students who study in the physics track participated in the "Research Physics" program, when these students have motivation to learn. The "Research Physics" program is not open to all students. In addition, the research team included a pair of students and it was not possible to carry out the inquiry project in a team of three or individually. Therefore, future research studies should examine the research questions:

1. Larger populations.
2. The schools (and not in a regional class) or in other learning environments
3. The comparison between boys and girls.
4. A heterogeneous classroom that includes students from different levels of intelligence and different backgrounds, when the gaps between the students in the general knowledge and motivation to learn are great.
5. Different configurations of number of students in the research team (a single student, pairs of students, three students, and so on).
6. A different duration of time of the performance of the inquiry work. In this research study, students acquired different inquiry practices during the three years of their studies in the 'Research Physics' Program. It is reasonable to assume that the time apparently has impact on the students' development in the different inquiry practices and impact on the perceptions of the inquiry process as a whole. An interesting question to examine is as follows. What is the range of time in which there is change in the development of the students in the acquisition of inquiry practices? These research studies will add additional dimensions to the feasibility of inquiry-based teaching and learning.

6. References

- ABRAHAMS, I., & MILLAR, R. (2008) Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education*, 30, 1945–1969.
- ACHERET CENTER WEBSITE: MULTICULTURAL CENTER FOR INQUIRY WORKS IN PHYSICS IN THE HIGH SCHOOL (n.d.) <http://www.acheret.org.il>. (Hebrew)
- AKERSON, V. L., & HANUSCIN, D. L. (2007) Teaching nature of science through inquiry: Results of a 3-year professional development program. *Journal of Research in Science Teaching*, 44(5), 653 - 680.
- AKKERMAN, S. F., & BAKKER, A. (2011) Boundary crossing and boundary objects. *Review of Educational Research*, 81(2), 132-169.
- ALBERTS, B. (2000) Some thoughts of a scientist on inquiry. In J. Minstrell & E. H. van Zee (Eds.). *Inquiring into Inquiry Learning and Teaching in Science* (pp. 3-13). Washington, DC: American Association for the Advancement of Science.
- ALESANDRINI, K. & LARSON, L. (2002). Teachers bridge to constructivism. *The Clearing House*, 119-121
- ALEKSANYAN, A. (2020) Motivational, engaged and reflective teaching competences in quality teacher education. *Studies on Quality Teachers and Quality Initial Teacher Education*, 285-296.
- ALON, B.S., BANGO, A., BERGER, H., MAGEN, A., WEISSMAN, A., HAJ-YAHI, ...& LANGLEY, D. (2009) Course for Leading Teachings – Physics Is Learned Differently, Physics Teachers Website: <http://ptc.weizmann.ac.il/?pg=login&Flag=&SectionKey=&CatID=1428&PathInfo=%2F%3FCategoryID%3D1428>. (Hebrew)
- ANDERSON, R. D. (2002) Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education* 13, 1-12.
- AVERY, L., TRAUTMANN, N., & KRASNY, M. (2003) Impacts of participation in a GK- 12 fellowship program on teachers' conceptions and use of inquiry science. Paper presented at the meeting of the National Association for Research in Science Teaching, Philadelphia, PA. Retrieved April 2, 2007, from http://ei.cornell.edu/pubs/NARST_CEIRP_03.pdf.
- AXINN, W. G. & PEARCE, L. D. (2006) *Mixed method data collection strategies*. New York: Cambridge University Press
- BAIRD, J.R. (1990) Metacognition, purposeful enquiry and conceptual change. In E. Hegarty-Hazel (Ed.). *The Student Laboratory and the Science Curriculum*, (183-200). Routledge, London.
- BARON, J. B. (1990) Performance assessment: Blurring the edges among assessment, curriculum, and instruction. In A. B. Champagne, B. E. Lovitts, & B. J. Calinger (Eds), *Assessment in the Service of Instruction: This Year in School Science 1990*. Washington, DC: American Association for the Advancement of Science.
- BARROW, L. H. (2006) A brief history of inquiry: From Dewey to standards. *Journal of Science Teacher Education*, 17, 265-278.
- BARTELS, B. H. (1998) Integrating the disciplines in the elementary grades with problem-based learning. *The Delta Kappa Gamma Bulletin*, 64(3), 9-14.
- BELL, R. L., BLAIR, L. M., CRAWFORD, B. A., & LEDERMAN, N. G. (2003) Just do it? Impact of a science apprenticeship program on high school students' understanding of the nature of science and scientific inquiry. *Journal of Research in Science Teaching*, 40(5), 487-509.
- BEN DAVID, A. (2012) The process of scientific inquiry in the classroom: From theory to practice. *Eureka*, 33, 1-19. (Hebrew)
- BEN DAVID, A., & ZOHAR, A. (2009) Contribution of meta-strategic knowledge to scientific inquiry learning. *International Journal of Science Education*. 31(12), 1657-1682.
- BENCZE, L., BOWEN, M., & ALSOP, S. (2006) Teachers' tendencies to promote student-led science projects: Associations with their views about science. *Science Education*, 90(3), 400-419.
- BENJAMIN, S. (1989) An Ideascap for education: What futurists recommend. *Educational Leadership*, 47(1), 8 -14.
- BERG, C. A. R., BERGENDAHL, V. C. B., LUNDBERG, B. K. S., & TIBELL, L. A. E. (2003) Benefiting from an open-ended experiment? A comparison of attitudes to, and outcomes of, an expository versus an open-inquiry version of the same experiment. *International Journal of Science Education*, 25(3), 351-372.

- BEYT MAROM, R. (1990) *Research methods in the social sciences* (unit 2). The Open University Press. (Hebrew)
- BEYT MAROM, R., & ASHKENAZI, M. (2012) *Research methods in the social sciences* (unit 4). The Open University Press. (Hebrew)
- BIRENBOIM, M. (1997) *Alternatives in the Assessment of Achievements*. Tel Aviv: Ramot Press. (Hebrew)
- BIRENBOIM, M. (2009) Assessment for learning and characteristics of a school professional community and class culture that empower it, In Y. Keshti (Ed.) *Assessment, Jewish Education, and History of Education: A Collection in the Memory of Professor Aryeh Levi, ZL* (pp. 77-144). Tel Aviv: Ramot. (Hebrew)
- BITON, Y. (2011) *Incorporating peer assessment in pre-academic mathematics study*. Ph.D. Dissertation, The Department of Education in Science and Technology, Technion, Haifa.
- BLACK, P., & WILLIAM, D. (1998) Assessment and classroom learning. *Assessment in Education*, 5 (1) 7-74.
- BRANCO WEISS INSTITUTE WEBSITE. Process of Inquiry. Retrieved from: <http://www.branco weiss.org.il/1091/>. (Hebrew)
- BROWN, P. L., ABELL, S., K, DEMIR, A., & SCHMIDT, F. (2006) College science teachers' views of classroom inquiry. *Science Education*, 90(5), 784-802
- BYBEE, R. W. (1997) *Achieving Scientific Literacy*. London: Heineman.
- BYBEE, R. W. (2000) Teaching science as inquiry. In J. Minstrel & E.H. Van-Zee (Eds.). *Inquiring into Inquiry Learning and Teaching in Science*. Washington DC; AAAS.
- CASTELLO, M., & MONEREO, C. (1999) Teaching learning strategies in compulsory secondary education. Paper presented at the 8th European Conference for Research on Learning and Instruction, August, Goteborg, Sweden.
- CAULEY, K., & MCMILLAN, J. (2010). Formative assessment techniques to support student motivation and achievement. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 83 (1), 1-6.
- CHABAY, R., & SHERWOOD, B. (2008) Computational physics in the introductory calculus-based course. *American Journal of Physics*, 76.4 (2008): 307-313
- CHI, M. T. H. (1997) Quantifying qualitative analyses of verbal data: A practical guide. *The Journal of the Learning Sciences*, 6(3), 271-315.
- CHIN, C. (2004) Students' questions: Fostering a culture of inquisitiveness in science classrooms. *School Science Review*, 86(314), 107-112.
- CHIN, C., & CHIA, L. (2006) Problem-based learning: Using ill-structured problems in biology project work. *Science Education*, 90(1), 44-67.
- CHIN, C., & OSBORNE, J. (2008). Students' questions: A potential resource for teaching and learning science. *Studies in Science Education*, 44, 1-39.
- CHINN, C. A., & MALHOTRA, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education*, 86(2), 175-218.
- CHINN, C., & CHIA, L. (2004) Problem-based learning: Using students' questions to drive knowledge construction. *Science Education*, 88(5), 707-727.
- COHEN, A., & REICH, M. (2014) Archimedes Point – School for teacher-researchers in physics: The way to change the teaching of physics in Israel, The 15th Annual Scientific Conference: Research, Study, and Creation in Oranim College. (Hebrew)
- COLLINS, A., BROWN, J. S., & HOLUM, A. (1991) Cognitive apprenticeship: Making thinking visible. *American Educator*, 15.3, 6-11.
- COLLINS, A., BROWN, J. S., & NEWMAN, S. (1989) Cognitive apprenticeship: Teaching the craft of reading, writing and mathematics. In L. B. Resnick (Ed.), *Knowing learning and instructions: Essays in honor of Robert Glaser* (pp. 453-494). Hillsdale, NJ: Lawrence Erlbaum Associates.
- COSTENSON, K., & LAWSON, A. E. (1986) Why isn't inquiry used in more classrooms? *The American Biology Teacher*, 48(3), 150-158.
- CRAWFORD, B. A. (2007) Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching*, 44(4), 613-642.
- CRESWELL, J. W., & PLANO CLARK, V. L. (2011) *Designing and conducting mixed methods research*. (2nd ed.). Thousand Oaks, CA: Sage.
- CRESWELL, J. W., PLANO CLARK, V. L., GUTMANN, M. L., & HANSON, W. E. (2003) Advanced mixed methods research designs. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social and behavioral research* (pp. 209–240). Thousand Oaks, CA: Sage
- CRESWELL, J.W. (2003) *Research design: qualitative and quantitative, and mixed approaches*, Thousand Oaks, CA: Sage.

DAVIDSON INSTITUTE FOR SCIENTIFIC-PHYSICS AND INDUSTRY EDUCATION WEBSITE (n.d.) http://davi-web.weizmann.ac.il/excellent/school_of_contemporary_science/phys-ind (Hebrew)

DEBOER, G.E. (2000) Scientific literacy: Another look at its historical and contemporary meaning and its relationship to science education reform. *Journal of Research in Science Teaching*, 37, 582-601.

DENZIN, N.K. (1978) *The research act* (2nd ed.), New York: McGraw-Hill.

DEPARTMENT FOR PLANNING AND DEVELOPMENT OF CURRICULA (2016) *Curriculum in Physics for the Upper School: 5 Units of Study*. Jerusalem: Ministry of Education. From the website http://cms.education.gov.il/EducationCMS/Units/Tochniyot_Limudim/Physics/5/AlHatochnit/Ekronot.htm (Hebrew)

DEPARTMENT FOR TEACHING SCIENCES IN THE WEIZMANN INSTITUTE OF SCIENCE, PHYSICS AND INDUSTRY WEBSITE (n.d.) https://stwww1.weizmann.ac.il/?page_id=733 (Hebrew)

DEPARTMENT OF SCIENCES – CHEMISTRY (2016) Structure of an inquiry laboratory. Ministry of Education of the State of Israel http://cms.education.gov.il/EducationCMS/Units/Mazkirut_Pedagogit/Chimya/YechidatHamaabada/Shalavim/ (Hebrew)

DEWEY, J. (1910) Science as subject-matter and as method. *Science*, 28, 121-127.

DEWEY, J. (1938) *Logic: The Theory of Inquiry*. New York: Holt, Rinehart & Winston.

DOMIN, D. S. (1999). A review of laboratory instruction styles. *Journal of Chemical Education*, 76, 543-547.

DREYFUS, E. (2006) Training teachers for management of inquiry activity under the constructivist influence, In A. Zohar (Ed.) *Learning through Inquiry: A Continuous Challenge* (pp. 166-168). Jerusalem: Magnes Press. (Hebrew)

EDWARDS, C. H. (1997) Promoting student inquiry. *Science Teacher*, 64(7), 18-21.

ETKINA, E., MURTHY, S., & ZOU, X. (2006). Using introductory labs to engage students in experimental design. *American Journal of Physics*, 74, 979-986.

ETKINA, E., & VAN HEUVELEN, A. (2007) Investigative Science Learning Environment - A science process approach to learning physics. In E. F. Redish & P. Cooney (Eds.), *PER-based Reforms in Calculus-Based Physics* (Vol. 1, pp. 1-48): College Park, MD: American Association of Physics Teachers.

ETKINA, E., VAN HEUVELEN, A. & MILLS, D. (2002) Role of experiments in physics - A process approach. *The Physics Teacher*, 40, 351-355.

EVEN-SHOSHAN, A. (1969) *The New Dictionary of the Literary, Scientific, and Spoken Hebrew Language with Hebrew and Aramaic Sayings and International Terms in Seven Volumes*, Jerusalem: Kiryat Sefer Press. (Hebrew)

EVEN-SHOSHAN, A. (1969) *The New Dictionary of the Literary, Scientific, and Spoken Hebrew Language, with Hebrew and Aramaic Expressions, International Terms, in Seven Volumes*. Jerusalem: Kiryat Sefer Ltd. (Hebrew)

EXPLORATORIUM INSTITUTE FOR INQUIRY WORKSHOP WEBSITE. (n.d.) <https://www.exploratorium.edu/educatoin/ifi/workshops>

FLAVELL, J. H. (1976) Metacognitive aspects of problem solving. In L. B. Resnick (Ed), *The Nature of Intelligence* (pp. 231-235). Hillsdale, NJ: Lawrence Erlbaum Associates.

FLAVELL, J. H. (1979) Metacognition and cognitive monitoring: A new area of cognitive developmental inquiry. *American Psychologist*, 34(10), 906-911.

FURTAK, E. M. (2006) The problem with answers: An exploration of guided scientific inquiry teaching. *Science Education*, 90(3), 453 - 467.

GANDHI, P. R., LIVEZEY, J. A., ZANIEWSKI, A. M., REINHOLZ, D. L., & DOUNAS-FRAZER, D. R. (2016) Attending to experimental physics practices and lifelong learning skills in an introductory laboratory course, *Am. J. Phys.* 84, 696.

GERMANN, P. J., HASKINS, S., & AULS, S. (1996) Analysis of nine high school biology laboratory manuals: Promoting scientific inquiry. *Journal of Research in Science Teaching*, 33, 475 - 499.

GIBSON, H. L., & CHASE, C. (2002) Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. *Science Education*, 86(5), 693-705.

GIRAULT, I., D'HAM, C., NEY, M., SANCHEZ, E., & WAJEMAN, C. (2012) Characterizing the Experimental Procedure in Science Laboratories: A preliminary step towards students experimental design. *International Journal of Science Education*, 34(6), 825-854.

GOODNOUGH, K. (2006) Enhancing pedagogical content knowledge through self study: An exploration of problem-based learning. *Teaching in Higher Education*, 11(3), 301-318.

GOTT, R., & DUGGAN, S. (1995) *Investigative Work in the Science Curriculum*. Buckingham: Open University Press, 25-40.

- GREENE, J. C., CARACELLI, V.J., & GRAHAM, W.F. (1989) Toward a conceptual framework for mixed-method evaluation designs, *Educational Evaluation and Policy Analysis*, 11(3), 255-274.
- GREENE, J.C., & CARACELLI, V.J. (1997) *Advances in mixed-method evaluation: the challenges and benefits of integrating diverse paradigms* (New Directions for Evaluation, no. 74), Jossey-Bass, San Francisco.
- GROSSMAN, P., WINEBURG, S., & WOOLWORTH, S. (2001) Toward a theory of teacher community. *Teachers College Record*, 103 (6), 942-1012
- GUBA, E.G. & LINCOLN, Y.S. (1994). Competing Paradigms in Qualitative Research. In: Denzin, N.K., & Lincoln, Y.S., (Eds.) *Handbook of Qualitative Research*. London: Sage Publications.
- GUBA, E.G. & LINCOLN, Y.S. (1998). Competing paradigms in qualitative research. In: Denzin, N.K., & Lincoln, Y.S., (Eds.) *The Landscape of Qualitative Research*. London: Sage Publications.
- GUBA, E.G. AND LINCOLN, Y. (2005) "Paradigmatic Controversies, Contradictions, and Emerging Confluences", in Denzin N. et Lincoln Y., (Eds.), *Handbook of Qualitative Research*, Thousand Oaks, CA: Sage, 3ème Ed., pp. 191-215.
- GUNSTONE, R. F. (1991) Reconstructing theory from practical experience. In B. Woolnough (Ed.). *Practical Science*, 67-77; Milton Keynes: Open University Press
- GUNSTONE, R.F., & CHAMPAGNE, A.B. (1990) Promoting conceptual change in the laboratory. In E. Hegarty-Hazel (Ed.) *The Student Laboratory and the Science Curriculum*. (London: Routledge).
- HARLEN, W. (2003) Enhancing inquiry through formative assessment. *San Francisco: Exploratorium*. Retrieved from <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.128.5260&rep=rep1&type=pdf>
- HARLEN, W. (2004) *Evaluating inquiry-based science developments*. A paper commissioned by the National Research Council Board on Science Education NW, Washington Retrieved April 28, 2007, from http://www7.nationalacademies.org/bose/WHarlen_Inquiry_Mtg_Paper.pdf
- HARPAZ, Y. (2000) *The Pedagogy of Asking: Teaching and Learning in a Thinking Community – On the Way to a Thinking School*. Branco Weiss Institute and the Ministry of Education. (Hebrew)
- HATIVA, N. (2003) *Processes of Teaching in the Classroom*. Tel Aviv: Academic Press for the Development of the Teaching Faculty. (Hebrew)
- HENSON, K. (1986) Inquiry learning: A new look. *Contemporary Education*, 57(4), 181-183.
- HERITAGE, M. (2010) *Formative assessment: Making it happen in the classroom*, Thousand Oaks, CA: Corwin Press.
- HERRON, M. D. (1971) The nature of scientific enquiry. *School Review*, 79, 171 - 212.
- HMELO-SILVER, C. E. (2004) Problem-based learning: What and how do students learn? *Educational Psychology Review*, 16(3), 235-266.
- HODSON, D. (1990) A critical look at practical work in school science. *School Science Review*, 71, 33 - 40.
- HODSON, D. (1996) Laboratory work as scientific method: three decades of confusion and distortion. *Journal of Curriculum Studies*, 28, 115-135.
- HOFSTEIN, A. & LUNETTA, V. N. (2004) The laboratory in science education: Foundation for the 21st century. *Science Education*. 88, 28-54.
- HOFSTEIN, A., & LUNETTA, V. N. (1982) The role of the laboratory in science teaching: Neglected aspects of research. *Review of Educational Research*, 52, 201-217.
- HOFSTEIN, A., SHOR, R., KIPNIS, M. & LEVY NACHUM, T. (2007) Learning through inquiry in the chemistry laboratory. In: Zohar, E. (ed.). *Learning through Inquiry*. Jerusalem: Magnes Press. (Hebrew)
- HOFSTEIN, A., SHORE, R., & KIPNIS, M. (2004) Providing high school chemistry students with opportunities to develop learning skills in an inquiry-type laboratory: A case study. *International Journal of Science Education*, 26, 47-62.
- HOGAN, K., & BERKOWITZ, A.R. (2000) Teachers as inquiry learners. *Journal of Science Teacher Education*, 11(1), 1-25.
- HOLMES, N. G., & WIEMAN, C. E. (2016) Examining and contrasting the cognitive activities engaged in undergraduate research experiences and lab courses. *Physical Review Physics Education Research*, 12(2).
- HOWE, K.R. (1992) Getting over the quantitative-qualitative debate, *American Journal of Education*, 100 (2), 236–256.
- ILAN RAMON CENTER FOR SCIENCE LOVING YOUTH WEBSITE (n.d.) http://in.bgu.ac.il/ilanramon/Pages/2_points_project.aspx (Hebrew)
- JOHNSON, B., & TURNER, L. A. (2003) Data collection strategies in mixed methods research. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social and behavioral research* (pp. 297-319). Thousand Oaks, CA: Sage

- JOHNSON, R.B., & ONWUEGBUZIE, A.J. (2004) Mixed methods research: A research paradigm whose time has come, *Educational Researcher*, 33(7), 14-26.
- JOHNSON, R.B., ONWUEGBUZIE, A.J., & TURNER, L.A. (2007) "Toward a Definition of Mixed Methods research", *Journal of Mixed Methods Research*, vol. 1, no. 2, pp. 112-133
- KAPACH, Z. (2014) *From Traditional Laboratory to Inquiry-Based Laboratory in High-School Physics Instruction: Professional Development of Teachers*. Ph.D. Dissertation. Rechovot: Weizman Institute of Science. (Hebrew)
- KAPON, S. (2016). Doing research in school: Physics inquiry in the zone of proximal development. *Journal of Research in Science Teaching*, 53(8), 1172-1197.
- KEENAN, E. K. (2010) Seeing the forest and the trees: Using dynamic system theory to understand "stress and coping" and "trauma and resilience". *Journal of Behavior in the Social Environment*, 20 (8), pp. 1038–1060
- KEYS, C. W., & BRYAN, L. A. (2001) Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching*, 38(6), 631 - 645.
- KEYS, W.C., HAND, B., VAUGHN, P., & COLLINS, S. (1999) Using the science writing heuristic as a tool for learning from laboratory investigations in secondary science. *Journal of Research in Science Teaching*, 36, 1065-1084.
- KHISHFE, R., & ABD-EL-KHALICK, F. (2002) Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching*, 39(7), 551 - 578.
- KIRSCHENBAUM, H., & SIMON, S. (1974) Values and the futures movement in education. In A. Toffler (Ed.). *Learning for Tomorrow: The Role of the Future in Education* (pp. 257 - 270). New York: Random House.
- KRAJCIK, J., BLUMENFELD, P., MARX, R. W., & SOLOWAY, E. (2000) Instructional, curricular, and technological supports for inquiry in science classrooms. In J. Minstrell & E. H. Van Zee (Eds.), *Inquiring into Inquiry Learning and Teaching in Science* (pp. 283–315). Washington, DC: American Association for the Advancement of Science.
- KRAJCIK, J., CZERNIAK, C. & BERGER, C. (1999) *Teaching Children Science - A Project-Based Approach*, New York: McGraw-Hill College.
- KRAJCIK, J., MAMLOK, R., & HUG, B. (2001) Modern content and the enterprise of science: Science education in the twentieth century. In L. Corno (Ed.), *Education across a Century: The Centennial Volume* (pp. 205-238). Chicago: National Society for the Study of Education
- KRUPNIK-GOTTLIEB, M., & COHN, A. (2015) Physics and medicine in industry: A unique PBL model that combines science, medicine and entrepreneurship for high school gifted and talented students. In H.E. Vidergor & C.R. Harris (Eds.) *Applied Practice for Educators of Gifted and Able Learners*. (Chapter 24, pp. 527-542). Rotterdam, The Netherlands: Sense Publishers.
- KUHN, D., GARCIA MILA, M., ZOHAR, A. & ANDERSEN, C. (1995) Strategies of knowledge acquisition. *Monographs of the Society for Research in Child Development*, 60, Serial No. 245.
- LANGLEY, D., & ALON, B. (2007) Structuring of the integration of inquiry activities in the teaching of the sciences in the upper school: Challenges and instruments for solution. In: E. Zohar (Ed.) *Learning through Inquiry: Continuous Challenge* (pp. 114-187). Jerusalem: Magnes. (Hebrew)
- LANGLEY, D., ARIELI R., EYLON B.S. (2010) Enhancing four science learning dimensions: The physics & industry experience, GIREP-ICPE-MPTL 2010 Int'l. Conf. on Teaching and Learning Physics Today: Challenges? Benefits? Reims, France, 22-27 August 2010, 108-109.
- LAWSON, A. E., ET AL. (1991) Hypothetico-deductive reasoning skill an concept acquisition: Testing a constructivist hypothesis, *Journal of Research in Science Teaching*, 28, 953-970.
- LEECH, N., & ONWUEGBUZIE, A. (2008) A typology of mixed methods research designs, *Quality and Quantity*, 43(2), March, 265-275.
- LIDAR, M., LUNDQVIST, E., & ÖSTMAN L. (2006) Teaching and learning in the science classroom: The interplay between teachers' epistemological moves and students' practical epistemology. *Science Education*, 90(1), 148-163.
- LINN, M. (1992) Science education reform: Building on the research base. *Journal of Research in Science Teaching*, 29, 821-840.
- LOH, B., RADINSKY, J., REISER, B. R., GOMEZ, L. M., EDELSON, D. C., & RUSSELL, E. (1997) The progress portfolio: Promoting reflective inquiry in complex investigation environments. Paper presented at the conference on Computer Supported Collaborative Learning, Toronto, Canada.
- LONNER, W. J. (2009) Introduction to the special issue: Qualitative and mixed methods research in cross-cultural psychology. *Journal of Cross-Cultural Psychology*, 40, 907-908.

- LOYENS, S.M.M. & RIKERS, R.M.J.P. (2011) Instruction based on inquiry. In: E.E. Mayer, & P. A. Alexander (eds.) *Handbook of Research on Learning and Instruction*. New York: Routledge Press.
- LUCKIE, D. B., MALESZEWSKI, J. J., LOZNAK, S. D., & KRHA, M. (2004) Infusion of collaborative inquiry throughout a biology curriculum increases student learning: a four-year study of "Teams and Streams". *Advances in Physiology Education*, 28, 199-209.
- LUNETTA, V. N. (1998) The school science laboratory: Historical perspectives and contexts for contemporary teaching. In: Fraser, J.B. & Tobin, K.G. (eds.). *International Handbook of Science Education*. Kluwer Academic Publishers.
- LUNETTA, V. N., & TAMIR, P. (1979) Matching lab activities with teaching goals. *The Science Teacher*, 46, 22 - 24.
- MARKHAM, T. (2011) Project Based Learning. *Teacher Librarian*, 39(2), 38-42.
- MARTIN-HANSEN, L. (2002) Defining inquiry: Exploring the many types of inquiry in the science classroom. *The Science Teacher*, 69(2), 34-37.
- MCDERMOTT, L. C., SHAFFER, P. S., & CONSTANTINOU, C. P. (2000) Preparing teachers to teach physics and physical science by inquiry. *Physics Education*, 35, 411-416.
- NATIONAL RESEARCH COUNCIL (1996) *The National Science Education Standards*. Washington, DC: National Academy Press.
- NATIONAL RESEARCH COUNCIL (2000) *Inquiry and the National Science Education Standards*. Washington, D.C: National Academy Press.
- NATIONAL RESEARCH COUNCIL (2005) *America's Lab Report: Investigations in High School Science*. Washington, D.C: National Academy Press.
- NATIONAL RESEARCH COUNCIL (2012) *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: National Academy Press.
- NATIONAL RESEARCH COUNCIL. (2013). *Next Generation Science Standards (NGSS): For States, By States*. Washington, DC: The National Academies Press.
- OGENS, E. M. (1991) A review of science education: past failures, future hopes. *The American Biology Teacher*, 53(4), 199-203.
- ONWUEGBUZIE A. J., & LEECH N. L. (2005) Taking the "q" out of research: teaching research methodology courses without the divide between quantitative and qualitative paradigms, *Quality & Quantity: International Journal of Methodology*, 39 (3), 267-295
- ORNSTEIN, A. (2006) The frequency of hands-on experimentation and student attitudes toward science: A Statistically significant relation. *Journal of Science Education and Technology*, 15 (3), 285-297.
- OSBORN, J. M., & KARUKSTIS, K. K. (2009) The benefits of undergraduate research, scholarship, and creative activity, in: M. Boyd & J. Wesemann (Eds.), *Broadening Participation in Undergraduate Research: Fostering Excellence and Enhancing the Impact* (pp. 41-53). Washington, DC, Council on Undergraduate Research.
- OSBORNE, J., SIMON, S. & COLLINS, S. (2003). Attitudes towards science: a review of the literature and its implications. *International Journal of Science Education*, 25, 1049- 1079.
- PAPERT, S. (1993) *The Children's Machine: Rethinking School in the Age of the Computer*. New York: Basic Books.
- PATTON, M. Q. (1990) *Qualitative Evaluation and Research Methods* (2nd ed.). Newbury Park, CA: Sage Publications, Inc.
- PAULSON, F. L., PAULSON, P. R., & MEYER, C. A. (1991) What makes a portfolio a portfolio, *Educational Leadership*, 48(5), 60-63.
- PEDAGOGICAL SECRETARY (2008) *The Assimilation of Inquiry in the Educational System in Israel*. Jerusalem. The Ministry of Education. From the website: http://cms.education.gov.il/EducationCMS/Units/Mazkirut_Pedagogit/OfekPedagogi/Lemida_Cheker/ (Hebrew)
- PEDAGOGICAL SECRETARY (2009) High order thinking strategies – Guiding document for national and local curricula and for developers of learning materials. Ministry of Education, Department for the Planning and Development of Curricula. Retrieved from the website: http://meyda.education.gov.il/files/Tochniyot_Limudim/Portal/EstrategyotChashiva.pdf (Hebrew)
- PEDAGOGICAL SECRETARY (2015) Paths to meaningful teaching – Leverage of applied models for meaningful teaching, Jerusalem: Ministry of Education of Israel, 29-34. Retrieved from the website: <http://meyda.education.gov.il/files/MinhalPedagogiy/netivim.pdf> (Hebrew)

- PERKINS, D. (1995) The apple of the tree of knowledge for education – Teaching and learning for understanding, *Education of Thinking*, 4, Branco Weiss Institute for the Cultivation of Thinking, 25-34. (Hebrew)
- PERL, D (2019) *Students' perception of a learning progression: from semi-structured inquiry activities to an open ended research project*, Master thesis, The Weizmann Institute of Science, Israel.
- PESSIG, D. (2000) *Thinking and Learning Abilities*. Ramat Gan: Bar-Ilan University. (Hebrew)
- PHYSICS AND MEDICINE IN INDUSTRY PROGRAM WEBSITE (n.d.) <http://mofetnet.macam.ac.il/course/Default.aspx?id=3563> (Hebrew)
- PHYSICS SUPERVISOR COORDINATOR (2009) *Circular of the Physics Supervisor Coordinator*, December. Ministry of Education, Website of the Physics Supervisor Coordinator: http://cms.gov.il/EducationCMS/Units/Mazkirut_Pedagogit/Phizika/SholchanHmafmar/Hozer.htm (Hebrew)
- PHYSICS SUPERVISOR COORDINATOR (2015) *Circular of the Physics Supervisor Coordinator*, October. Ministry of Education, From the website of the Physics Supervisor Coordinator: http://cms.education.gov.il/EducationCMS/Units/Mazkirut_Pedagogit/Phizika/SholchanHmafmar/Hozer.htm (Hebrew)
- PHYSICS SUPERVISOR COORDINATOR (2016) *Circular of the Physics Supervisor Coordinator*, September. Ministry of Education, Retrieved from the website of the Physics Supervisor Coordinator: http://cms.education.gov.il/EducationCMS/Units/Mazkirut_Pedagogit/Phizika/SholchanHmafmar/Hozer.htm (Hebrew)
- PLUCKER, J., & NOWAK, J. (1999) How to use problem-based learning in the classroom. *Roeper Review*, 22(1), 69-70.
- PUSHKIN, D. B. (1997) Where do ideas for students come from? *Journal of College Science Teaching*, 26, 238-242.
- RAHM, A. (2012). *Project Based Learning Community: The Pedagogy for the Third Age*, Kiryat Beinayim. (Hebrew)
- REICH, M, COHEN, A., & HOCHSTATER, Y. (2009) ACHERET – Multicultural Fraternity of Researchers: The Jewish Arab Center for Inquiry Work in Physics in the Western Galilee, *Resonance – Newspaper for Physics Teachers in Israel*, 28 (1), 53-62. (Hebrew).
- REISER, B. J. (2004) Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *The Journal of the Learning Sciences*, 13.3, 273-304.
- RITCHIE, S. M., & RIGANO, D. L. (1996). Laboratory apprenticeship through a student research project. *Journal of Research in Science Teaching*, 33(7), 799-815.
- ROBERTS, R. (2001) Procedural understanding in biology: "Thinking behind the doing". *Journal of Biological Education*, 35(3), 113-117.
- ROBERTS, R., & GOTT, R. (1999) Procedural understanding: Its place in the biology curriculum. *School Science Reviews*, 81, 19.
- ROBERTS, R., & GOTT, R. (2000) Procedural understanding: How is it characterized in texts. *School Science Reviews*, 82, 83.
- ROZENFELD, S., & FLIK, A. (2002) *Learning through Projects (Teacher Guide)*, Department for Teaching Sciences, Weizmann Institute for Science. (Hebrew)
- RUSHTON, E. A. C., & REISS, M. J. (2019) From science teacher to 'teacher scientist': Exploring the experiences of research-active science teachers in the UK. *International Journal of Science Education*, 41(11) 1541-1561. <https://doi.org/10.1080/09500693.2019.1615656>
- RUTHERFORD, F. J. (1964) The role of inquiry in science teaching. *Journal of Research in Science Teaching*, 2, 80-84.
- SABAR BEN-YEHOSHUA, N. (1990) *Qualitative research in teaching and learning*. Ramat Gan; Masada. (Hebrew)
- SABAR BEN-YEHOSHUA, N. (1999) *Qualitative Research in Teaching and Learning*. Modan Press. (Hebrew)
- SABAR BEN-YEHOSHUA, N. (2001) Introduction: The History of Qualitative Research, Influences and Currents, in N. Sabar Ben-Yehoshua (ed.) *Traditions and Currents in Qualitative Research* (pp. 13-28). Lod: Dvir Press. (Hebrew)
- SADEH, I., & ZION, M. (2009) The development of dynamic inquiry performances within an open inquiry setting: A comparison to guided inquiry setting. *Journal of Research in Science Teaching*, 46 (10), 1137-1160
- SADLER, P.M., & GOOD, E. (2006) The impact of self- and peer-grading on student learning. *Educational Assessment*, 11(1), 1-31.
- SADLER, R. (1989). Formative assessment and the design of instructional systems. *Instructional Science*, 18, 119-144

- SADLER, T.D., BURGIN, S., MCKINNEY, L., & PONJUAN, L. (2010). Learning science through research apprenticeships: A critical review of the literature. *Journal of Research in Science Teaching*, 47(3), 235-256.
- SAGE, S. M., & TORP, L. T. (1997) What does it take to become a teacher of problem based learning? *Journal of Staff Development*, 18, 32-6.
- SALOMON, J. (2000) *Technology and Education in the Era of Science*, Haifa University Press, Zmora Beitan. (Hebrew)
- SANDOVAL, W. A. (2005) Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education*, 89(4), 634-656.
- SANDOVAL, W.A., & REISER, B. J. (2004) Explanation-driven inquiry: Integrating conceptual and epistemic scaffolds for scientific inquiry. *Science Education*, 88(3), 345 - 372.
- SANDOVAL, W.A., & REISER, B.J. (1997) Evolving explanations in high school biology. (Eric Document Reproduction No. ED409165).
- SCHERZ, Z., & OREN, M. (2006) How to change students' images of science and technology. *Science Education*, 90(6), 965 - 985.
- SCHWAB, J. J. (1960) Inquiry, the science teacher, and the educator. *The School Review*. 68(2). 176-195.
- SCHWAB, J. J. (1962) The teaching of science as inquiry. In J. J. Schwab & P.E. Brandweine (Eds.), *The Teaching of Science*. Cambridge, Mass: Harvard University Press.
- SHEDLETZKY, E., & ZION, M. (2005) The essence of open-inquiry teaching. *Science Education International*, 16(1), 23-38.
- SHKEDI, A. (2003) *Words that Try to Touch: Qualitative Research – Theory and Implementation*, Tel Aviv: Ramot, 17-54. (Hebrew)
- SLATER, T. F. (1996) Portfolio assessment strategies for grading first-year university physics students in the USA. *Physics Education*, 31, 329-333.
- SPECTOR LEVY, A., & SHARTZ, Z. (2001) *Scientific Technological Communication – Collection for the Teacher*, Department for Teaching Science, Weizmann Institute of Science. (Hebrew)
- STAER, H., GOODRUM, D., & HACKLING, M. (1998) High school laboratory work in western Australia: Openness to inquiry. *Research in Science Education*, 28(2), 219-228.
- STIGGINS, R. (2005) From formative assessment to assessment for learning: A path to success in standards-based schools. *Phi Delta Kappan*, 87, 324-328.
- SOWELL, S., JOHNSTON, A., & SOUTHERLAND, S. (2007) Calling for a focus on where learning happens: A Response to Abd-El-Khalick and Akerson. *Science Education*, 91(1), 195-199.
- TAITELBAUM, D., MAMLOK-NAAMAN, R., CARMELI, M., & HOFSTEIN, A. (2008) Evidence for teachers' change while participating in a continuous professional development programme and implementing the inquiry approach in the chemistry laboratory. *International Journal of Science Education*, 30, 593-617.
- TAL, R., & ARGAMAN, S. (2005) Characteristics and difficulties of teachers who mentor environmental inquiry projects. *Research in Science Education* 35(4), 363 - 394
- TAMIR, P. (1971) Inquiry and teaching of biology. In A. Rivlin (Ed.). *Method – Study of Ways in Secondary Teaching of Biology (Collection 3)*, Tel Aviv: School of Education of Tel Aviv University Press, 163-178. (Hebrew)
- TAMIR, P. (1994). Israeli students' conceptions of science and views about the scientific enterprise. *Research in Science and Technological Education*, 12 (2), 99-116.
- TAMIR, P. (2007) Inquiry in teaching sciences and its reflection in the teaching of biology in Israel. In E. Zohar (Ed.) *Learning through Inquiry* (15-56), Jerusalem: Magnes Press. (Hebrew)
- TAMIR, P., STAVY, R., & RATNER, N. (1998) Teaching science by inquiry: Assessment and learning. *Journal of Biological Education*, 33(1), 27-32.
- TARHAN, L., & ACAR, B. (2007) Problem-based learning in an eleventh grade chemistry class: factors affecting cell potential. *Research in Science & Technological Education*, 25(3), 351-369.
- TASHAKKORI, A. & TEDDLIE, C. (Eds.) (2003) *The handbook of mixed methods in the social and behavioral sciences*. Thousand Oaks, CA: Sage
- THOMAS, J.W. (2000) A review of research on PBL, Online, June, from: http://www.Bobpearlman.org/BestPactices/PBL_Research.pdf.
- TOBIN, K. (1990) Research on science laboratory activities: In pursuit of better questions and answers to improve learning. *School Science and Mathematics*. 90 (5). 403-418.
- TRAUTMANN, N. M., & MAKINSTER, J. G. (2005) Teacher/scientist partnerships as professional development: Understanding how collaboration can lead to inquiry. Presented at the AETS 2005 International Conference, Colorado Springs, CO, January, Retrieved April 25, 2007, from http://ei.cornell.edu/pubs/AETS_CSIP_%2005.pdf

- TRAUTMANN, N., AVERY, L., KRASNY, M., & CUNNINGHAM, C. (2002) University science students as facilitators of high school inquiry-based learning. Poster presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April. Retrieved April 25, 2007, from http://ei.cornell.edu/pubs/CEIRP_NARST_02.pdf
- VYGOTSKY, L. S. (2004) Tools and Signs in the Development of the Child. In M. Tsellermeir & A. Kozolin (Eds.) *Learning in the Social Context*. Tel Aviv: HaKibbutz HaMeuchad. (Hebrew)
- VYGOTSKY, L.S. (1978) *Mind in Society: The Development of Higher Psychological Processes*. Cambridge MA: Harvard University Press.
- WALKINGTON, H., & RUSHTON, E.A.C. (2019) *Ten Salient Practices for Mentoring Student Research in Schools: New Opportunities for Teacher Professional Development*. Canadian Center of Science and Education.
- WALLACE, C. S., & KANG, N. H. (2004) An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing belief sets. *Journal of Research in Science Teaching*, 41, 936-960
- WATSON, R. & MANNING, A. (2008) Factors influencing the transformation of new teaching approaches from a programme of professional development to the classroom. *International Journal of Science Education*, 30(5), 689-709.
- WELCH, W.W., KLOPFER, L.E., AIKENHEAD, G.S., & ROBINSON, J.T. (1981) The role of inquiry in Science Education: Analysis and recommendations. *Science Education*, 65(1), 33 - 50.
- WIEMAN, C., & HOLMES, N. G. (2015) Measuring the impact of an instructional laboratory on the learning of introductory physics. *American Journal of Physics*, 83(11), 972-978.
- WINDSCHITL, M. (2003) Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice?. *Science Education*, 87(1), 112 - 143.
- WINDSCHITL, M., THOMPSON, J., & BRAATEN, M. (2008) Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science Education*, 92, 941-967.
- WOODS, P. (1996) *Researching the Art of Teaching: Ethnography for Educational Use*. London: Routledge.
- WU, H. K., & HSIEH, C. E. (2006) Developing sixth graders' inquiry skills to construct explanations in inquiry-based learning environments. *International Journal of Science Education*, 28(11), 1289 - 1313.
- YEN, C., & HUANG, S. (2001) Authentic learning about Tree Frogs by preservice biology teachers in open-inquiry research settings. *Proceedings of the National Science Council*, Republic of China, ROC(D), 11(1), 1 - 10.
- YERRICK, R. K. (2000) Lower track science students' argumentation and open inquiry instruction. *Journal of Research in Science Teaching*, 37(8), 807 - 838.
- YIP, D. Y. (1999) Implications of students' questions for science teaching. *School Science Review*, 81(294), 49-53.
- YOSHIKAWA, H., WEISNER, T. S., KALIL, A. & WAY, N. (2008) Mixing qualitative and quantitative research in developmental science: Uses and methodological choices. *Developmental Psychology*, 44 (2), pp. 344-354.
- ZEMACH, M., & BEYT-MAROM, R. (1986). *Research Methods in the Social Sciences: Research Principles and Styles*, Unit 5: The Survey. Tel Aviv: The Open University. (Hebrew)
- ZION, M., SLEZAK, M., SHAPIRA, D., LINK, E., BASHAN, N., BRUMER, M., ORIAN, T., NUSSINOWITZ, R., COURT, D., AGREST, B., MENDELOVICI, R., & VALANIDES, N. (2004). Dynamic, open inquiry in Biology learning. *Science Education*, 88(5), 728 - 753.
- ZION, M., COHEN, S. & AMIR, R. (2007) The spectrum of dynamic inquiry teaching practices. *Research in Science Education*, 37(4), 423-447.
- ZOHAR, A. (2007) Inquiry learning, high thinking skills, and meta-cognition. In A. Zohar (Ed.), *Learning through Inquiry: A Continuous Challenge*. Magnes Press, Chapter 2, 57-84. (Hebrew)
- ZOHAR, A. (Ed.) (2006) *Learning through Inquiry: A Continuous Challenge*. Jerusalem: Magnes Press. (Hebrew)
- ZOHAR, A., & BEN DAVID, A. (2008) Explicit teaching of meta-strategic knowledge in authentic classroom situations. *Metacognition and Learning*, 3(1), 59-82.
- ZOHAR, A., & NEMET, F. (2002) Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching*, 39, 3-62.