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The Impact of Inquiry Based Learning Approach on Secondary School Students' Science Process Skills

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Abstract

The aim of this research was to investigate the effect of science course which is based on inquiry based learning approach on seventh grade students' scientific process skill levels. Both quantitative and qualitative data collection methods were used in the study. Considering that both quantitative and qualitative data collection methods were used, the study involved a mixed-method design. The research process was carried out according to the simultaneous transformational mixed research design. The study group consisted of 40 students at seventh grade who were studying in public schools in a district in the western part of Turkey in the 2016-2017 academic year. The data analysis was carried out with Scientific Process Skills Scale and Semi-Structured Interview Form. The obtained data were analyzed using statistical methods. As a result of the study, it was determined that the scientific process skill levels of the students in the experimental group increased statistically significantly compared to the students in the control group. Additionally, the results obtained in the analysis of qualitative data support the results obtained from the quantitative data.

Keywords: Science education, inquiry based learning approach, secondary school students, scientific process skills, student opinions.

1. Introduction

Nowadays, it is more important to teach students how to reach scientific knowledge instead of giving it directly. Students should be provided with opportunities to grow up as individuals who investigate, question, think critically, and manage their own learning process. In this regard, educators have been supporting students' learning through direct experiments for a long time. This issue was dealt by John Dewey in 1916 with the emphasis that understanding scientific method is more important than memorizing scientific knowledge (Lederman, 1992). It is stated that students learn better through direct experiments for a specific purpose, providing

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real-life content, methods and perspectives (Dewey, 1933, as cited in Dell'Olio & Donk, 2007). It is important to design strong learning environments based on constructivist approach-based learning processes for effective teaching (Sahranç, 2011).

- There is no statistically significant difference in the general science process skills (SPS) pre-test scores between the experimental group and control group, but there is a statistically significant difference in the SPS post-test scores between the groups. Considering the mean ranks of the groups in the table 2, this difference is in favor of the experimental group.
- It is found that there is a statistically significant difference between general SPS level the pre-test and post-test scores of the experimental group. Considering the means of the test scores, it is seen that this difference is in favor of the post-test scores. On the contrary, there is no statistically significant difference between the means of pre-test and the post-test scores of the control group (Table 3).
- The findings obtained from the quantitative data coincide with the findings obtained from the qualitative data in the research.

In our country, it is emphasized that, in 2013 and 2017 Science Curriculums, the Inquiry-based Learning (IBL) approach is preferred, in which the student is responsible for his/her own learning, and this approach enables the student to actively participate in the learning process and allows the student to construct information in his/her own mind (MoNE, 2013; MoNE, 2017). The IBL approach is based on the teaching-learning strategy developed by J. Dewey (Şahan, Uyangör & Işıtan, 2012). The inquiry-based method in science education has been a popular field of study for science literacy criteria since 1993 and for science education with the National Science Education Standards prepared by the National Research Council (NRC) since 1996 (Lederman, Abell & Akerson, 2008). The IBL approach is based on teaching science contents based on science, and it is a comprehensive approach where scientific inquiry and teaching strategies are used together in the teaching process (Bybee, 2006). In this approach, students use inquiry to reach ideas and theories that help them explain what they observe, such as scientists, to understand what is happening around them and the facts of nature (Duban, 2014). There is a learning cycle that follows the sequence of developing a question, constructing a hypothesis, developing an experimental design, collecting and recording data, analyzing data, reaching results, constructing and extending generalizations, and sharing results in an inquiry-based teaching process (Dell'Olio & Donk, 2007). In order for a student to succeed in the process of IBL, earn *learning outcomes*, understand the way scientists work, the student must have readiness to ask questions about the inquiry process, design research, and collect and analyze data. Moreover, they must have readiness to use evidences, establish connections with questions and answers. The ability of the student to produce scientific questions in the learning process is an essential feature (NRC, 2000; Jesus, Souza, Teixeira-Dias & Watts, 2005). In this regard, the teacher should guide the connection between scientific ideas and experimental data in the IBL process (Varelas, 1996; Metz, 2004). Students should be encouraged to formulate questions within the learning environment and to avoid subjectivity and to make predictions about the subject without being obsessed with objectivity, and thus new perspectives and possibilities will be considered (Zandvliet, 2013). It should be remembered that a rich learning process will be experienced with the emergence of different perspectives and practices in the process of IBL.

While IBL activities are used to improve students' inquiry skills, "real" is used to raise awareness of conducting a scientific study and prepare them to critically address scientific issues (Filippi & Agarwal, 2017). Moreover, the IBL approach is a powerful learning tool for the development of individuals as it supports understanding the nature of science, acquiring scientific knowledge and scientific process skills, and the establishment of scientific thinking (Fang, Lamme & Pringle, 2010). Through the inquiry method, students learn to use scientific knowledge and processes as well as use critical thinking and reasoning skills to identify and formulate their problems. Furthermore, they earn a deeper understanding of the nature of science and scientific processes as a result of their active participation in discussing, explaining, and researching science-related events and issues, and develop their scientific thinking skills (Fang et al., 2010). The IBL approach makes it easier for students to perceive the real world and provides opportunities for them to use all kinds of science concepts, principles, and laws they have learned in the classroom to solve real-life problems (Duban, 2014).

Researches on IBL also supports the effectiveness of the IBL approach. In the study conducted by Wilson, Taylor, Kowalski and Carlson (2010) investigating the effectiveness of the IBL, it is stated that the students in the experimental group have showed significantly higher achievement in acquisition way such as knowledge, reasoning, discernment, and discussion than the students in the control group and that this difference has been maintained both immediately after the study and at the end of the four-week period. In the study carried out by Kuhn and Pease (2008) in which the IBL approach was applied, it is stated that in the development of the students followed up year by year, the students have made significant progress in understanding the inquiry objectives, identifying questions, expressing ideas, defining models, controlling comparisons, interpreting data that is becoming more complex, supporting claims and developing validated predictions overtime, and that they can apply the scientific method properly. In the study carried out by Bunterm, Lee, Ng Lan Kong, Srikoon, Vangpoomyai, Rattanavongsa and Rachahoon (2014), some learning outcomes were examined based on guided and structured inquiry-based learning. As a result of this research, it is stated that there is a significant positive difference on science knowledge and science process skills of both groups. In the study conducted by Van Uum, Verhoeff and Peeters (2017), the effect of teacher guidance on the learning process of the students is investigated, and it is concluded that the open IBL process could be initiated with the use of intensive guidance by the teachers, and it is detected that the use of lightened guidance in addition to the intensive guidance has improved the students' scientific understanding and contributed to the formation of a common guidance process between the teacher and the student during learning and that students could acquire scientific knowledge and skills to direct their own learning process over time.

Also, the studies carried out on the basis of the IBL approach within the scope of the research performed are considered important in terms of providing students the opportunity to improve their scientific process skills (SPS) levels by conducting scientific inquiry activities and providing the opportunity to conduct research and construct information using a scientific method. Based on this study, it is envisaged that the IBL approach may serve as an example of its applicability in science courses and that the IBL approach can provide an example of how it can be applied in science courses. It is thought that the prepared worksheets can be used in different academic studies and science courses in secondary schools and present ideas for new researches in the literature related to the research topic. In this context, in this study, it was aimed to investigate the effect of the IBL approach on the SPS level of seventh grade students. Moreover, it was aimed to determine the students' views on the applications of the IBL process. For this purpose, the following the sub-problems are examined:

- At the end of the application process, is there a statistically significant difference in basic SPS levels between the experimental group students to whom the IBL approach was applied in the science course and the control group students to whom the 2013 Science Education Program was applied in the science course?
- At the end of the application process, is there a statistically significant difference in high-level SPS levels between the experimental group students to whom the IBL approach was applied in the science course and the control group students to whom the 2013 Science Education Program was applied in the science course?

- What are the opinions of the experimental group students towards the application of the IBL process?

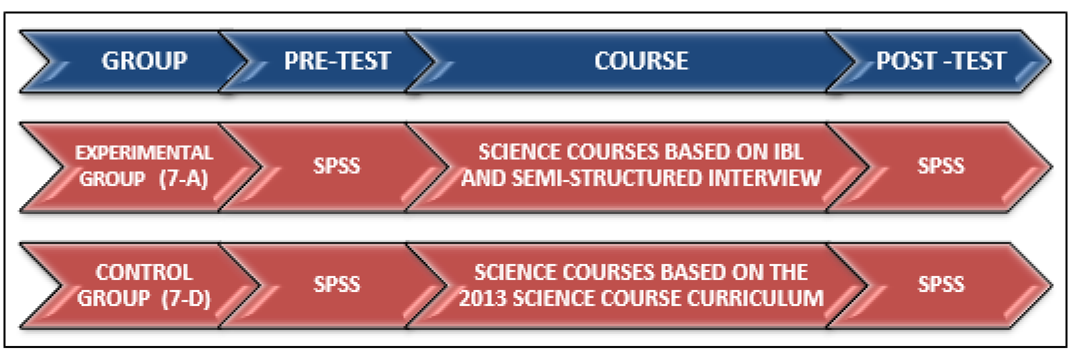
2. Method

2.1 *Research model*

The aim of scientific research in social sciences is to understand the complexity of human behavior and experiences. The task of the researcher is to understand, explain, and describe this complex structure within the limits of research methods (Morse, 2003). Although the techniques and methods used to reach scientific facts play an important role, one of them alone is not enough. In this respect, it is necessary to get closer to reality using more than one method (Türkdoğan, 2000). The use of quantitative and qualitative approaches in social research provides a better understanding of the research problem and a complex phenomenon, broadens the boundaries of the research, and provides answers to research questions from different perspectives (Morse, 2003; Creswell & Plano Clark, 2011). Research designs created by combining various qualitative and quantitative research methods are called mixed research (Morse, 2003).

In this research, since both quantitative and qualitative data collection methods were used together, the research involved a mixed method. The research process was carried out according to the simultaneous transformational mixed research design. In this design, quantitative and qualitative data are collected and analyzed at the same time. Priority is given to qualitative or quantitative data types, but in some cases equal importance can be given to both data types. Data analysis is performed separately, and combining usually occurs during the data interpretation stage or when data are transformed during data analysis. It is useful for providing a wide range of alternatives or perspectives, supporting the participants, and providing a better understanding of the phenomenon being studied (Creswell, 2003).

In this research, after the pre-test of the Science Process Skills Scale (SPSS), the science course was carried out in the experimental group according to the IBL approach while the control group was conducted based on the 2013 science course curriculum. Qualitative data were collected from experimental group with semi-structured interview form in order to support quantitative data during the IBL process. At the end of the process, SPSS was applied to both experimental and control groups as post-test. The steps applied in the research are detailed in Model 1.



Model 1. Research model

In the research, the quantitative data obtained from the pre-test and post-tests were examined by statistical methods and the qualitative data were examined by content analysis.

2.2 *Working group*

This research was conducted with 40 students at seventh grade level who were studying in a public school in a district western part of Turkey in 2016-2017 academic year. These students consisted of two classes of twenty individuals. With the random assignment, one of the classes was included in the study as the experimental group and the other as the control group. The science teacher, one of the authors of the article, provided the science courses of both groups. While a small number of students in the experimental and control groups lived in economic conditions at the upper or lower income level, the students of both groups generally had moderate economic opportunities. The experimental group consisted of 12 boy and eight girl students, and the control group consisted of 11 boy and nine girl students. The school where the research was carried out was that 450 students were studying, there is no conference hall, there is no indoor gymnasium, and there is no equipped science laboratory; however, it is a public school with moderate physical conditions with science course materials sent by MoNE in the science class, where there is a class that can be used as a science class.

2.3 *Data collection tools*

In the research, SPSS was used for the collection of quantitative data and a semi-structured interview form was used for the collection of qualitative data.

2.3.1 *Scientific process skills scale*

As a data collection tool, SPSS developed by Aydoğdu, Tatar, Yıldız and Buldur (2012) was used. SPSS consists of 27 multiple-choice items. Nine of the items are aimed at measuring basic skills and 18 of them measured high level skills. At the basic level, there are items for observing, classifying, using space/time relations, making predictions, making inferences; on the other hand, at the high level, there are items for problem solving, hypothesis building, determining and controlling variables, conducting experiments, and interpreting data. In order to determine the scientific process skills of all students in the second stage of primary education, the reliability coefficient (KR – 20) of the proposed measurement tool to be used in screening experimental studies is 0.84. Additionally, average difficulty is 0.54. The differences between the average scores of the students in the upper 27% and lower 27% of the measurement tool are statistically significant for each item ($p<0.05$). According to these results, it can be said that this measurement tool developed to measure the scientific process skills of elementary school students is valid and reliable (Aydoğdu, Tatar, Yıldız & Buldur, 2012).

2.3.2 *Semi-structured interview form*

In order to support the quantitative data collected in the study, qualitative data were collected from the experimental group students through a semi-structured interview form. The semi-structured interview form has developed by Yıldız (2008) and consists of eight questions.

2.4 *Preparation of worksheets*

The worksheets were prepared by the researcher, who was also the science teacher of the study group, in accordance with the seventh grade learning outcomes of the Science Education Program (MoNE, 2013), and by paying attention to the elements that might be of interest to the students and examining many studies about the IBL approach in the literature. Afterwards, the worksheets were re-submitted to the expert opinion by making necessary arrangements by the researcher in accordance with the expert opinion. The worksheets were used in the lessons after finalizing the preparation process according to expert opinion. In line with the learning outcomes, a worksheet was created for each subject included in the course process. Each worksheet consisted of 4-6 pages. Students were not given ready-made problem situations on the worksheets; instead, scenarios were given to students on each worksheet. The scenarios were also prepared by the researcher who was the science teacher of the study group and prepared the worksheets. In the preparation of the scenarios, attention was paid to the development characteristics of the students, the content of the subject, and the quality of the students to reach the problem situations related to the subject. Considering the possibility that the students would see more than one problem situation that they could investigate in the scenarios, two sections in which the students should write their own sentences were presented on the worksheets. In both chapters, there were 10 parts: research problem, hypothesis, dependent variable, independent variable, control variables, tools and materials, trial plan, trial phase, observation-measurement and results, and evaluation. In both stages of the evaluation part, five or seven questions were given to the students to write their own sentences according to the subject characteristics.

2.5 *Inquiry-based learning process applied in the science class*

In order to collect quantitative data, SPSS was applied as a pre-test to the experimental and control group students before the application process and as a post-test at the end of the application process. Application process was carried out in both groups within the framework of "Force and Energy" unit learning outcomes. Within the scope of the Force and Energy Unit, five topics such a-as Pressure in Solids, Pressure in Liquids, Atmospheric Pressure, Gravitational Potential Energy and Kinetic Energy were discussed.

After the pre-tests, a small preparatory phase was applied to the experimental group students before starting the inquiry-based teaching process. In this preparatory phase, students were given the opportunity to make hypotheses, determine variables, and plan experiments by giving simple problem situations that should be investigated with short activities. Thus, it was aimed to facilitate the transition of students to open inquiry process. After the completion of the preparatory phase, the IBL process was carried out with five worksheets prepared for the subjects within the unit. Experimental group students carried out their studies in groups. In the formation of the groups, the students of the experimental group were divided into five groups of four persons, taking into consideration the volunteerism and wishes of the students. Each group carried out their studies and carried out in-group discussions, gathering on separate tables in the classroom layout where the large science-class desks of the school were placed according to the U-layout so that a large middle space could be used when needed.

The students were first given a working sheet on pressure in solids, and each student was asked to examine the sections in the worksheet, read and review the scenario given in the worksheet, and think about what ideas he had in mind before contacting each student's group friends. After the individual examinations were completed, the students were asked to discuss in groups for about 10 minutes to express their ideas about what they were thinking and to name their groups. In this process, it was stated that they should conduct their speeches within the framework of the following questions:

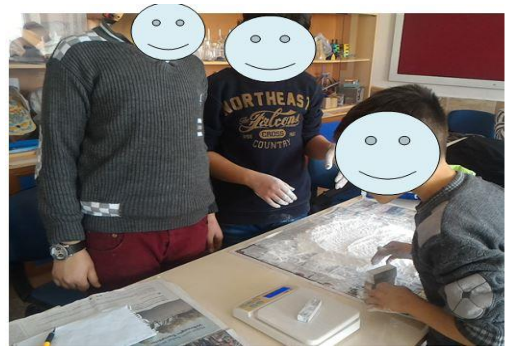
- Were there any situations that attracted your attention in the scenario, what was the situation that attracted your attention?
- What did you think about the situation that attracted your attention?
- After reading this scenario, was there any situation that you would like to investigate? If yes, what would be your research topic?
- What kind of problem statement did you express in your research?

While the groups continued their discussions within the framework of the above-mentioned questions, each group was guided separately by a teacher who was one of the researchers of the study. In the meantime, it was seen that although all groups could determine which point they would investigate jointly, they had difficulty in expressing the research topics with an appropriate problem sentence. At this point, each group was guided by asking different questions according to the needs of each group. The groups reorganized their problem sentences based on the awareness they obtained under teacher guidance in group discussions and asked the teacher to check the problem sentences. This guidance was continued until the appropriate problem was reached. While some groups were able to express research topics with a searchable problem sentence in the second control, some groups needed third or fourth guidance. Afterwards, all groups were asked to establish a hypothesis about their own research and to determine dependent, independent, and control variables in their research depending on the hypothesis they established. Guidance was provided to the groups who needed help in writing the variables and all groups were provided to complete the phase. After that, in order to carry out their research, all groups were asked to plan an experiment with the participation of all students in the group and decide which materials to be used in this experiment. After a few minutes of group discussion about the students' experimental plans, the groups were guided for the last time for this phase. After all the groups decided on the experimental plans, they were given time to complete the trial plan and equipment-materials sections on their worksheets with their own sentences. While filling this section, it was stated that they could visualize their expressions by making use of pictures and schemes. In the last minutes of the course, the materials that would be used by all groups were reviewed for detecting which ones could be found in the laboratory and which ones should be provided and the students were asked to come prepared by bringing simple materials that they could supply themselves.

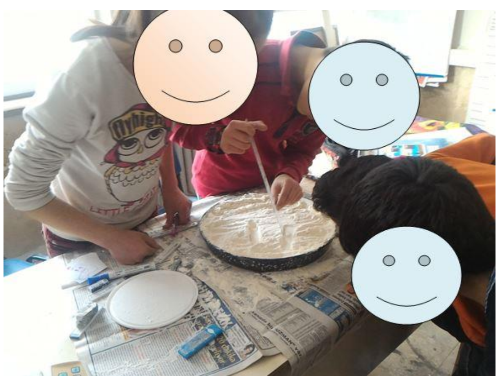
At the beginning of the next lesson, the students were asked to review their experiment plans in groups for two minutes. After the groups were ready to conduct their experiments, they were asked to conduct their experiments by reminding them that they should carefully record the data to be obtained from the experiments in the observation - measurement section. While conducting the experiments, the studies of all groups were observed one by one by the teacher, and guidance was provided to the groups where needed. After the groups completed their experiments, the students were asked to fill in the "trial phase" section on their worksheets with their own sentences and to indicate the results they obtained on the basis of the data based on their records. While the members of the group completed these sections of the worksheet, the students were also guided by the course teacher when necessary. Afterwards, all students were asked to formulate answers to the questions in the evaluation section. After that, a large group discussion environment was created and students were asked to express in which parts they had difficulty, how they offered solutions to these difficulties, and which stages they could easily handle. In this way, it was aimed to detect whether students developed awareness about their own learning and found the opportunity to compare their own learning processes with other students, and to reveal whether they could use learning ways of their friends in terms of social learning. In the ongoing section of the worksheet in the large group discussion, it was stated that the groups should be included in the discussion without sharing their hypotheses and experimental results because they would carry out a new research on the subject.

In the second part of the issue of pressure in solids, the groups were given the opportunity to work on another problem situation they wanted to investigate. At this stage, the students continued the IBL process in the sequence indicated in the first stage using the second part of the worksheet on the issue of pressure in solids. In the second part of the research, the students used the second part of the worksheets. After the completion of the second part of the worksheets and when there was no new research that all groups wanted to carry out on the subject, a final large group discussion was held for the whole subject. In the big group discussion, the students were asked what research question they started, what they thought in their hypothesis, how they designed a group experiment, what materials they used, which results they obtained from the data that they obtained, and what answers were written in the evaluation section of the worksheets. In the meantime, all students were asked to pay attention to the ideas, experiments, hypotheses, materials created by other groups, which were interested in, and to consider the work of other groups in comparison with their own work. Additionally, they were asked to compare the experiment they proposed and the one they applied as a result of the group decision.

Picture 1. Sample image from the moment of the students experimenting with fruits about pressure in solids.



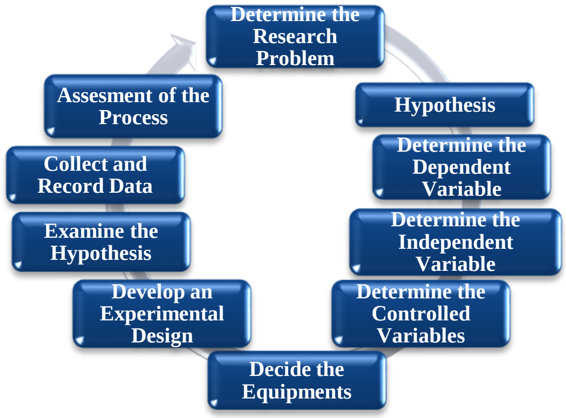
Picture 2. Sample image from the moment that the students repeated their measurements on pressure in solids.



Picture 3. Sample image from the moment that the students measured the depth of the traces on the flour ground.

Picture 4. Sample image from the students' experiments on kinetic energy.

Following the completion of the first activity, the other four activities were dealt in the stages specified in Model 2 in accordance with the IBL approach. At the end of each topic in the large group discussion, upon the request of the students, it was allowed that some groups repeat their experiments so that all students could see.



Model 2. The Stages of IBL in experimental group

In the control group, after the pre-test application in the same week with the experimental group, the learning outcomes were handled by adhering to the current curriculum without the IBL process. At the end of the process, as in the experimental group, the post-test application was performed.

3. The results

The quantitative data obtained from the pre-test and post-test using SPSS were analyzed using statistical methods. In the statistical analysis, before the application process of the experimental and control groups, the SPS level of the students before the application was examined in terms of the dependent variable of the study. Then, the levels of the groups at the end of the application process were examined, and the findings were formed. Furthermore, the data obtained from the groups were examined separately by single sample analysis within the group, and the findings were supported.

The Shapiro-Wilks test was used to determine whether the data obtained from the groups showed a normal distribution in order to examine the effect on general SPS levels of secondary school seventh grade students of the science course processed within the framework of the IBL approach. The Shapiro-Wilks test is used to examine the normality of the data if the group size is less than 50 (Büyüköztürk, 2015). The results of the Shapiro-Wilks test analysis are presented in Table 1.

Table 1. The Shapiro-Wilks test findings for general SPS scores

Test	Group	n	Z	p
General SPS in Pre-test	Experimental Group	20	0.949	0.355
	Control Group	20	0.908	0.059
General SPS in Post-test	Experimental Group	20	0.873	0.013*
	Control Group	20	0.929	0.148
General SPS Pre-test and Post-test Difference Scores	Experimental Group	20	0.944	0.289
	Control Group	20	0.966	0.678

*$p<0.05$

When Table 1 is examined, it is observed that general SPS scores show a normal distribution ($p>0.05$) in both groups in pre-test. On the other hand, in the last tests, while the general SPS score shows a normal distribution ($p>0.05$) in the control group, the general SPS score doesn't show a normal distribution ($p<0.05$) in the experimental group. In this respect, the independent samples t-test, a parametric method, was used to compare the general SPS pre-test scores of the groups. Additionally, the Mann Whitney U-test, a non-parametric method, was used to compare the last-test scores statistically. The results of the analysis are presented in Table 2.

Table 2. Unrelated measurements T and U-test results for general SPS Pre-Test and Post-Test scores of the experimental and control group students

Unrelated Measurements T-Test Results						
TEST	GROUP	N	$\overline{X}$	SS	t	p
Pre-test	Experimental Group	20	1.77	0.73	0.689	0.495
	Control Group	20	1.92	0.65		
Unrelated Measurements U-Test Results						
TEST	GROUP	N	Mean Rank	Sum of Rank	U	p
Post-test	Experimental Group	20	29.00	580.00	30.000	0.000*
	Control Group	20	12.00	240.00		

*p<0.05

When Table 2 is examined, it is found that there is no statistically significant difference between the general SPS pre-test scores of the groups (t=0.689; p>0.05), but there is a statistically significant difference between the post-test scores (U=30.000; p<0.05). Considering the mean ranks of the groups in the table, this difference is in favor of the experimental group.

The normality of pre-test and post-test difference scores was examined to determine the statistical method to be used to compare general SPS levels within the group before and after the application process. When Table 1 is examined, it is seen that the difference scores of both groups show normal distribution (p>0.05). In this respect, paired samples t-test, a parametric method, was used to compare the general SPS levels of both groups statistically. The results of the analysis are presented in Table 3.

Table 3. Related measures of T-test results for general SPS Pre-Test and Post-Test scores of the experimental and control group students

GROUP	TEST	N	$\overline{X}$	SS	sd	t	P
Experimental Group	Pre-test	20	1.68	0.85	19	11.077	0.000*
	Post-test	20	3.08	0.78			
Control Group	Pre-test	20	1.92	0.65	19	0.829	0.417
	Post-test	20	1.79	0.58			

*p<0.05

When Table 3 is examined, it is found that there is a statistically significant difference between general SPS level the pre-test and post-test scores of the experimental group (t=11.077; p<0.05). Considering the means of the test scores, it is seen that this difference is in favor of the post-test scores. On the contrary, there is no statistically significant difference between the means of pre-test and the post-test scores of the control group (t=0.829; p>0.05).

Table 4. The Shapiro-Wilks Test findings for basic SPS scores

Test	Group	n	Z	p
Basic SPS in Pre-test	Experimental Group	20	0.934	0.184
	Control Group	20	0.943	0.270
Basic SPS in Post-test	Experimental Group	20	0.873	0.013*
	Control Group	20	0.929	0.148
Basic SPS Pre-test and Post-test Difference Scores	Experimental Group	20	0.798	0.001*
	Control Group	20	0.888	0.025*

*p<0.05

The research also examined the effect of Science course, which was processed within the framework of IBL approach, on basic SPS levels of middle school seventh grade students. For this purpose, firstly, the Shapiro-Wilks test was used to determine whether the data showed a normal distribution in order to determine the statistical methods to be used in the analysis of the data related to the basic SPS level obtained from the groups. The results of the Shapiro-Wilks test analysis are presented in Table 4.

When Table 4 is examined, it is observed that the basic SPS scores of both groups show a normal distribution ($p>0.05$) whereas, in the post-tests, the basic SPS score of experimental group doesn't show a normal distribution ($p<0.05$). In this respect, independent samples t-test, a parametric method, was used to compare the basic SPS pre-test scores of the groups statistically. Moreover, the Mann Whitney U-test, a non-parametric method, was applied to compare the post-test scores of the groups statistically. The results of the analysis are presented in Table 5.

Table 5. Unrelated measurements T and U-test Results for basic SPS Pre-Test and Post-Test scores of the experimental and control group students

Unrelated Measurements T-Test Results						
TEST	GROUP	N	$\overline{X}$	SS	t	p
Pre-test	Experimental Group	20	1.95	0.78	0.290	0.773
	Control Group	20	2.02	0.55		
Unrelated Measurements U-Test Results						
TEST	GROUP	N	Mean Rank	Sum of Rank	U	p
Post-test	Experimental Group	20	28.75	575.00	35.000	0.000*
	Control Group	20	12.25	245.00		

p<0.05

When Table 5 is examined, it is seen that there is no statistically significant difference between the groups' basic SPS pre-test scores ($t=0.29$; $p>0.05$). On the other hand, there is a statistically significant difference between the basic SPS post-test scores of the groups ($U=35.000$; $p<0.05$). Considering the means of the groups in the table, this difference is in favor of the experimental group.

The normality of pre-test and post-test difference scores was examined to determine the statistical method to be used to compare the basic SPS levels within the group before and after the application process. When Table 4 is examined, it is seen that the difference scores of both groups do not show a normal distribution ($p<0.05$). In this respect, the Wilcoxon signed rank test, a non-parametric method, was used to compare the basic SPS levels of both groups statistically. The results of the analysis are presented in Table 6.

Table 6. Related measurements Wilcoxon signed rank test results for basic SPS Pre-Test and Post-Test scores of the experimental and control group students

GROUP	Pre- Post-test	N	Mean Rank	Sum of Rank	Z	p
Experimental Group	Negative Rank	0	0.00	0.00	3.87	0.000 *
	Positive Rank	19	10.00	190.00		
	Equality	1				
Control Group	Negative Rank	9	8.78	79.00	0.119	0.906
	Positive Rank	8	9.25	74.00		
	Equality	3				

*p<0.05

When Table 6 is examined, it is found that there is a statistically significant difference between basic SPS level the pre-test and post-test scores of the experimental group ($Z=3.87$; $p<0.05$). Considering the mean ranks and sum of ranks, it is seen that this difference is in favor of post-test scores. On the contrary, there is no statistically significant difference between the pre-test and post-test scores of basic SPS levels in the control group (Z=0.119; p>0.05).

The research also examined the effect of Science course, which was processed within the framework of IBL approach, on high level SPS levels of middle school seventh grade students. For this purpose, firstly, the Shapiro-Wilks test was used to determine whether the data showed a normal distribution in order to determine the statistical methods to be used in the analysis of the data related to the high level SPS level obtained from the groups. The results of the Shapiro-Wilks test analysis are presented in Table 7.

Table 7. The Shapiro-Wilks Test findings for high level SPS scores

Test	Group	n	Z	p
High Level SPS in Pre-test	Experimental Group	20	0.899	0.039
	Control Group	20	0.916	0.081
High Level SPS in Post-test	Experimental Group	20	0.796	0.001*
	Control Group	20	0.887	0.023*
High Level SPS Pre-test and Post-test Difference Scores	Experimental Group	20	0.905	0.051
	Control Group	20	0.973	0.816

*p<0.05

When Table 7 is examined, it is seen that the high level SPS pre-test scores show a normal distribution in the control group (p>0.05). However, it is seen that the high level SPS pre-test scores do not show a normal distribution in the experimental group (p<0.05). In the post-tests, it was observed that the high level SPS scores of both groups do not show a normal distribution (p<0.05). In this respect, the Mann Whitney U-test, a non-parametric method, was applied to compare the high level SPS pre-test and post-test scores of the groups. The results of the analysis are presented in Table 8.

Table 8. Unrelated measurements U-test results for high level SPS Pre-Test and Post-Test scores of the experimental and control group students

Unrelated Measurements U-Test Results						
TEST	GROUP	N	Mean Rank	Sum of Rank	U	p
Pre-test	Experimental Group	20	18.65	373.00	163.000	0.313
	Control Group	20	22.35	447.00		
Unrelated Measurements U-Test Results						
TEST	GROUP	N	Mean Rank	Sum of Rank	U	p
Post-test	Experimental Group	20	28.48	569.50	40.500	0.000*
	Control Group	20	12.53	250.50		

*p<0.05

When Table 8 is examined, it is seen that there is no statistically significant difference between the high level SPS pre-test scores of the groups (U=163.000; p>0.05). Additionally, there is a statistically significant difference between the groups' high level SPS post-test scores (U=40.500; p<0.05). Considering the mean ranks of the groups in the table, this difference is in favor of the experimental group.

The normality of pre-test and post-test difference scores was examined to determine the statistical method to be used to compare the high level SPS levels in the group before and after the application process. When Table 7 is examined, it is seen that the difference scores of both groups show a normal distribution (p>0.05). In this respect, paired samples t-test, a parametric method, was used to compare the high level SPS levels of both groups statistically. The results of the analysis are presented in Table 9.

Table 9. Related measurements T-test results for High Level SPS Pre-Test and Post-Test scores of the experimental and control group students

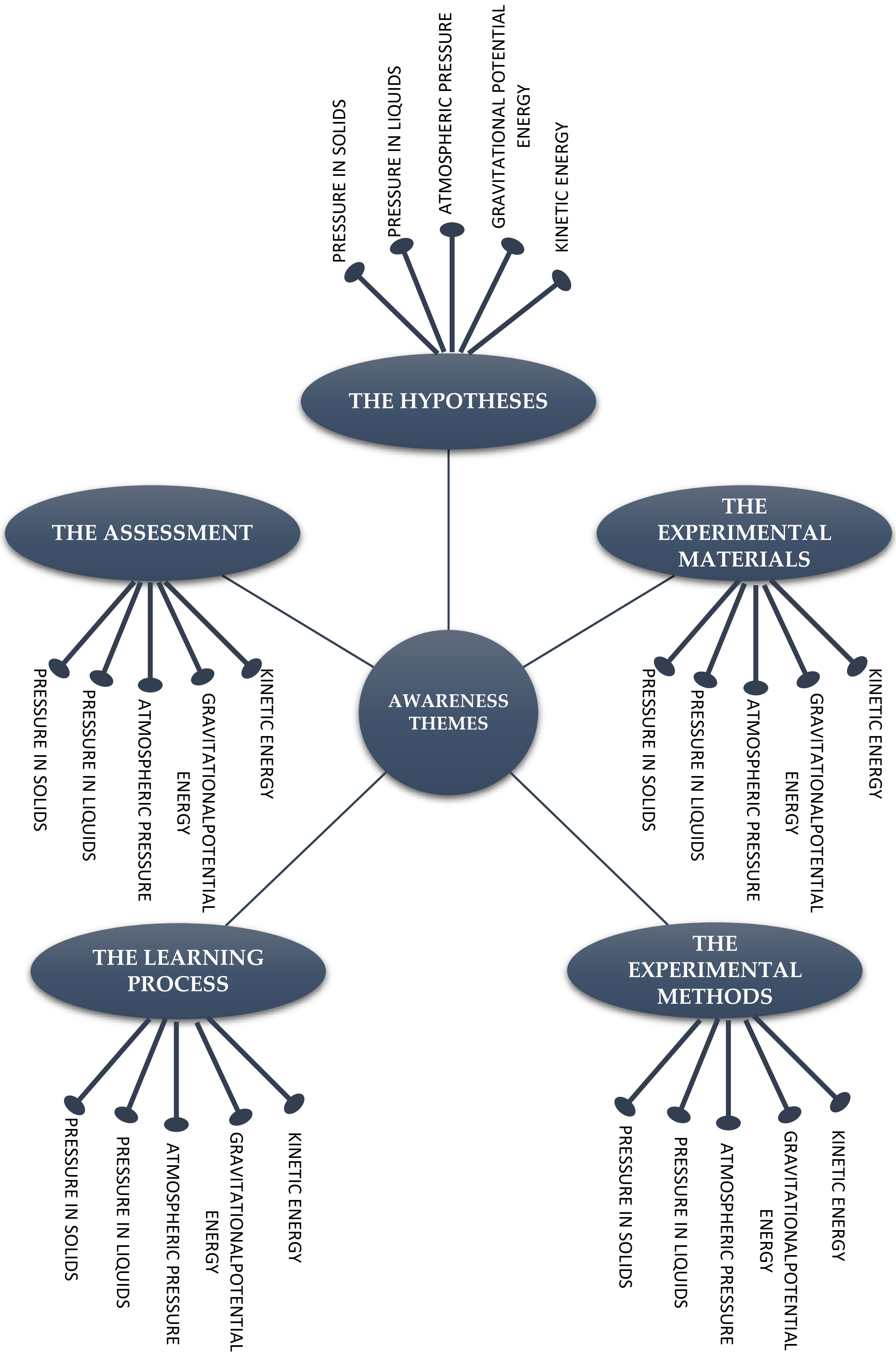
GROUP	TEST	N	$\overline{X}$	SS	sd	T	p
Experimental Group	Pre-test	20	1.95	0.78	19	11.332*	0.000*
	Post-test	20	3.11	0.47			
Control Group	Pre-test	20	1.87	0.75	19	1.146	0.266
	Post-test	20	1.66	0.63			

*p<0.05

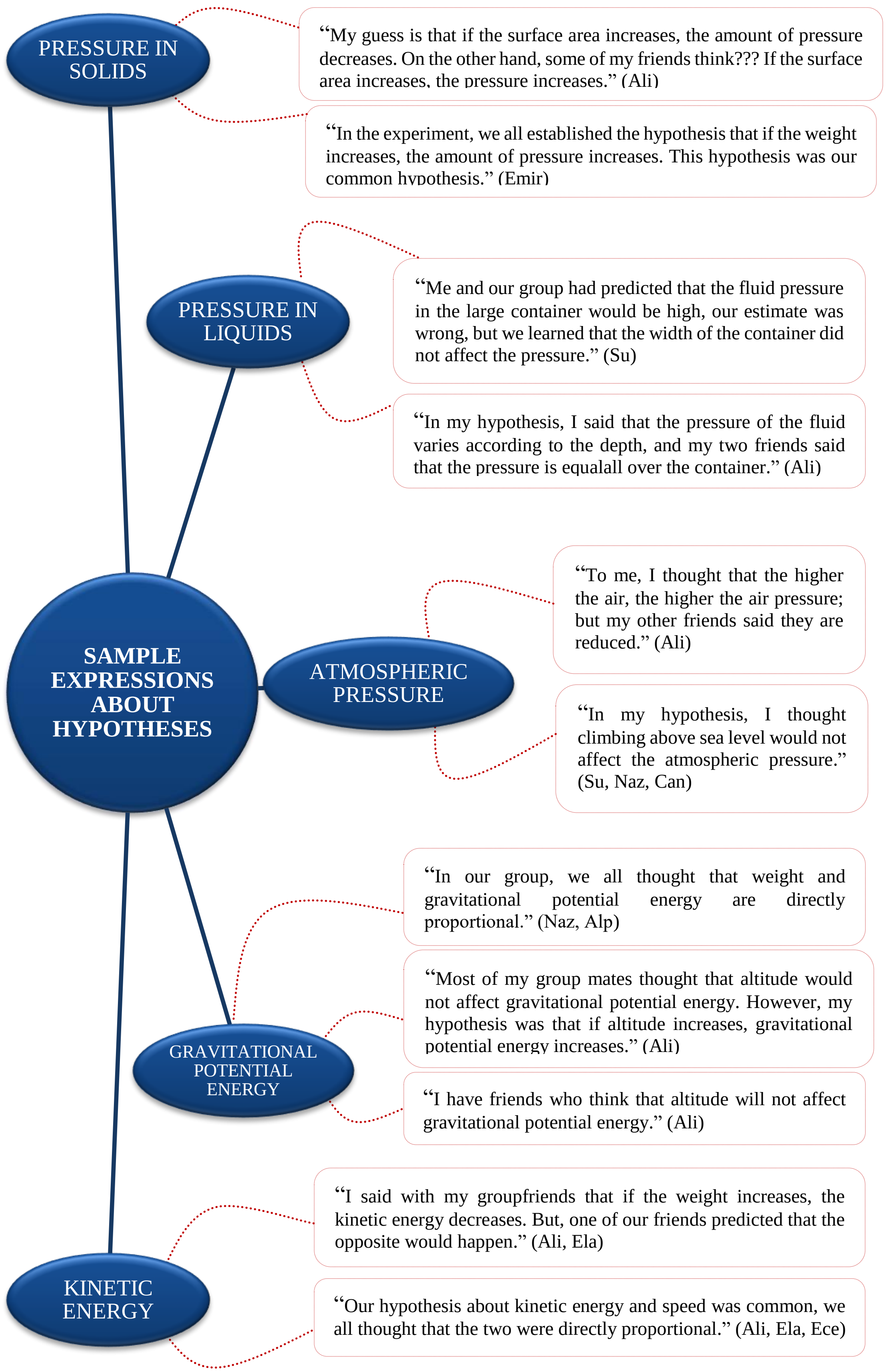
When Table 9 is examined, it is seen that there is a statistically significant difference between the high level SPS pre-test and post-test scores in the experimental group (T=11.332; p<0.05). Considering the means of the test scores, it is seen that this difference is in favor of the post-test scores. On the other hand, there is no statistically significant difference between the high level SPS pre-test and post-test scores in the control group (T=1.146; p>0.05).

In order to support the quantitative data obtained from the research, a semi-structured interview form was used. The interviews were conducted with 20 students in the experimental group regarding the inquiry-based teaching process. Instead of a single interview for the whole unit, the answers were collected separately for all subjects because of the possibility that the students could answer a different question for each subject in the unit. Content analysis was applied to the data obtained. In the analysis of the data, the opinions of three experts were consulted. As a result, the findings were presented with six models. In the models, the themes that emerged as a result of content analysis and the students' expressions were included. Students' expressions are not based on their real names; instead, a separate code name is provided for each student.

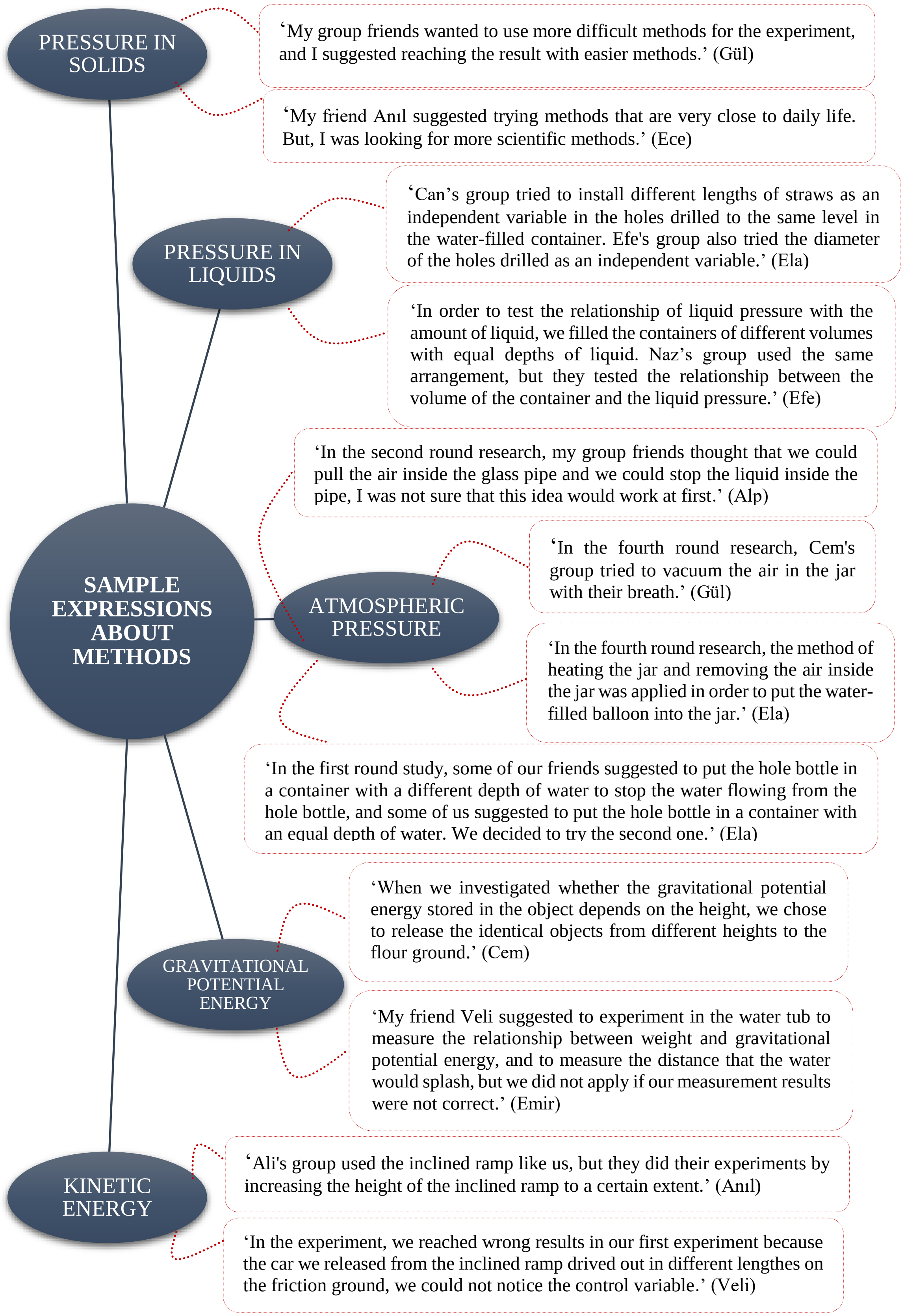
In the content analysis of the semi-structured interviews, it was seen that the students' expressions consisted of five themes. These themes are related to the hypotheses established during the IBL process, the materials used by the groups, the experimental methods applied by the groups, the learning process, and the assessment of the learning process. In each theme, it was noticed that the students expressed their opinions about all the subjects in the unit. Themes formed in the analysis of the data are presented in Model 3.



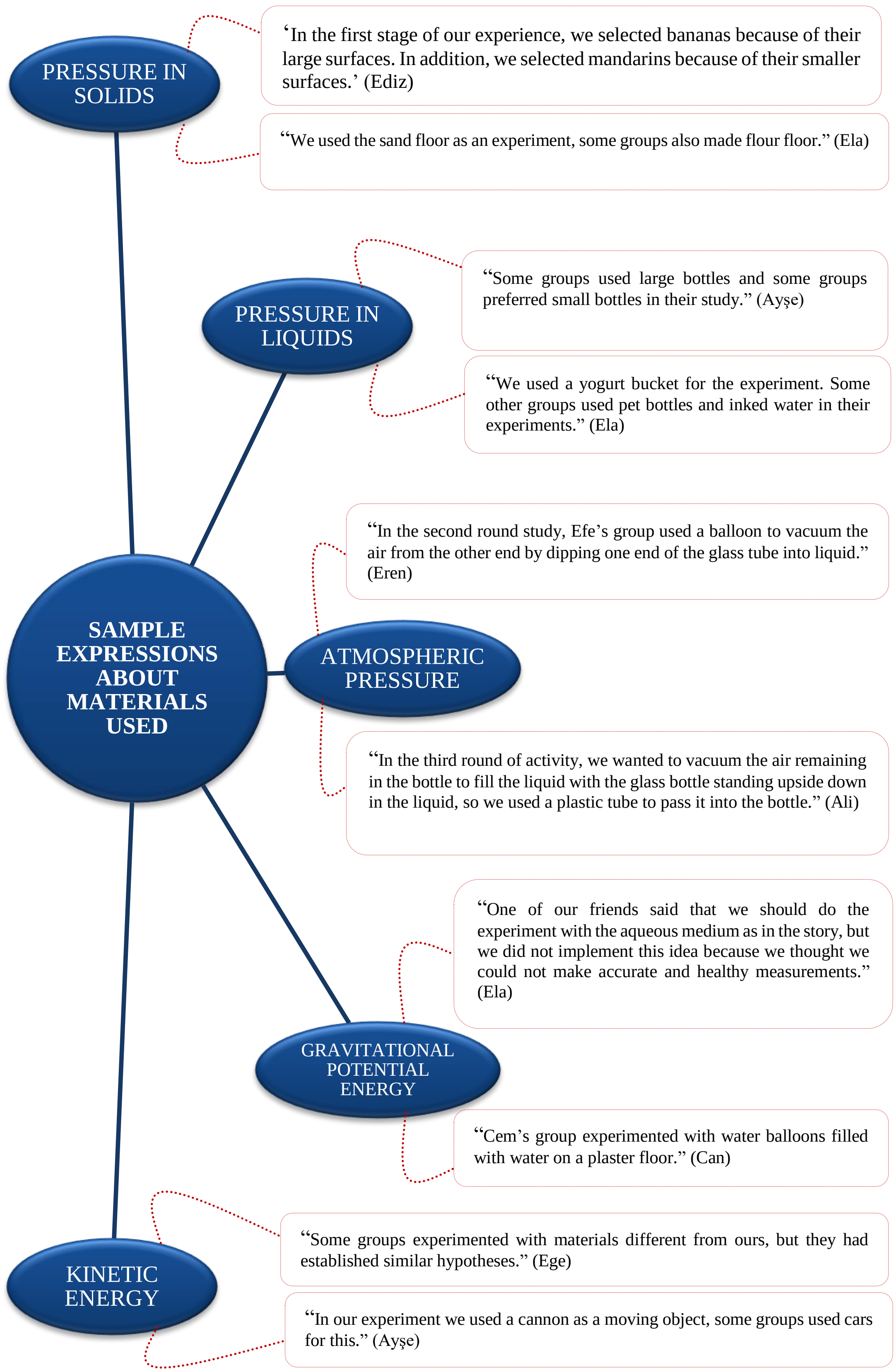
Model 3. Awareness themes related to the IBL process



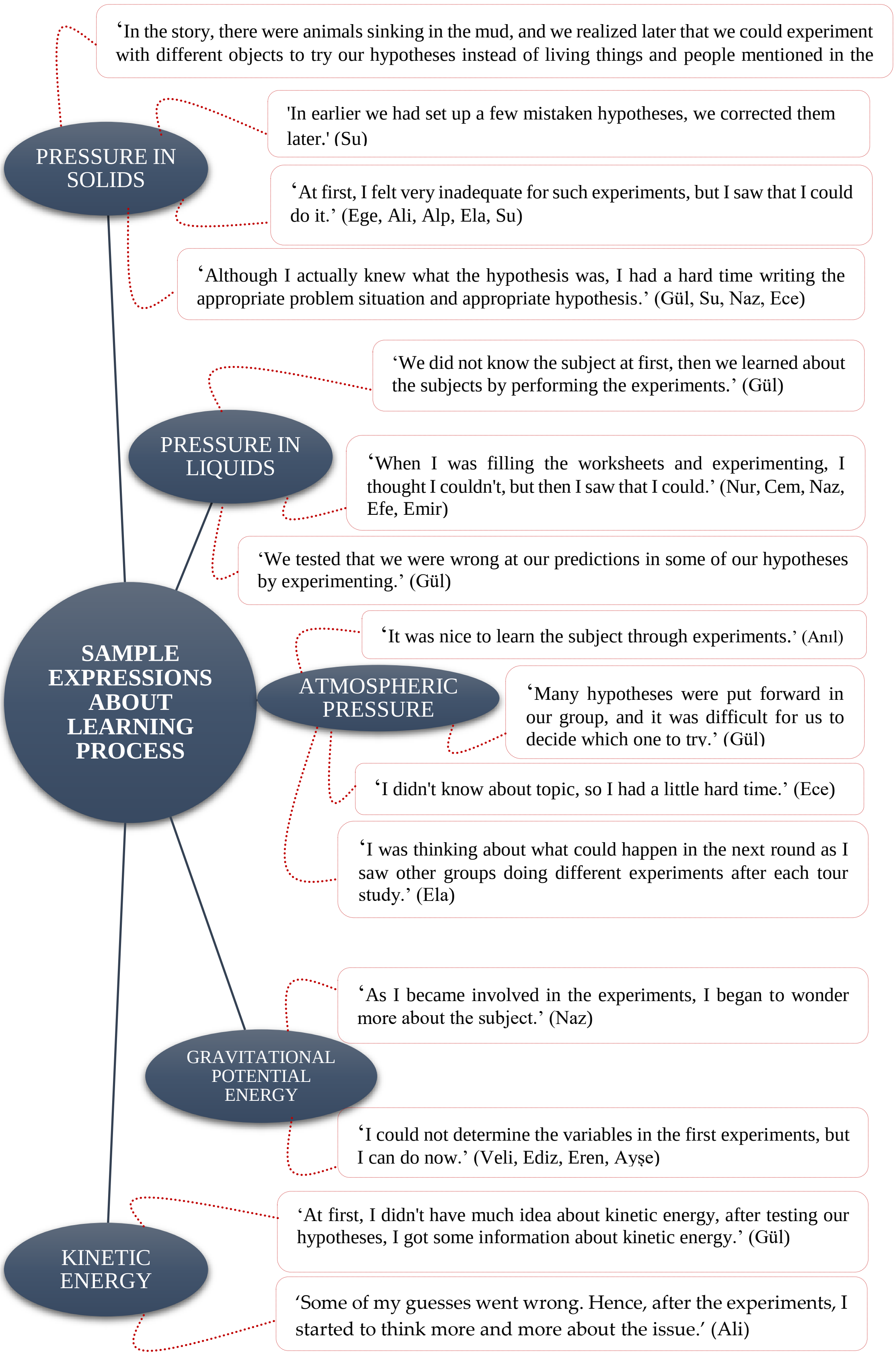
Model 4. Students' awareness about hypotheses



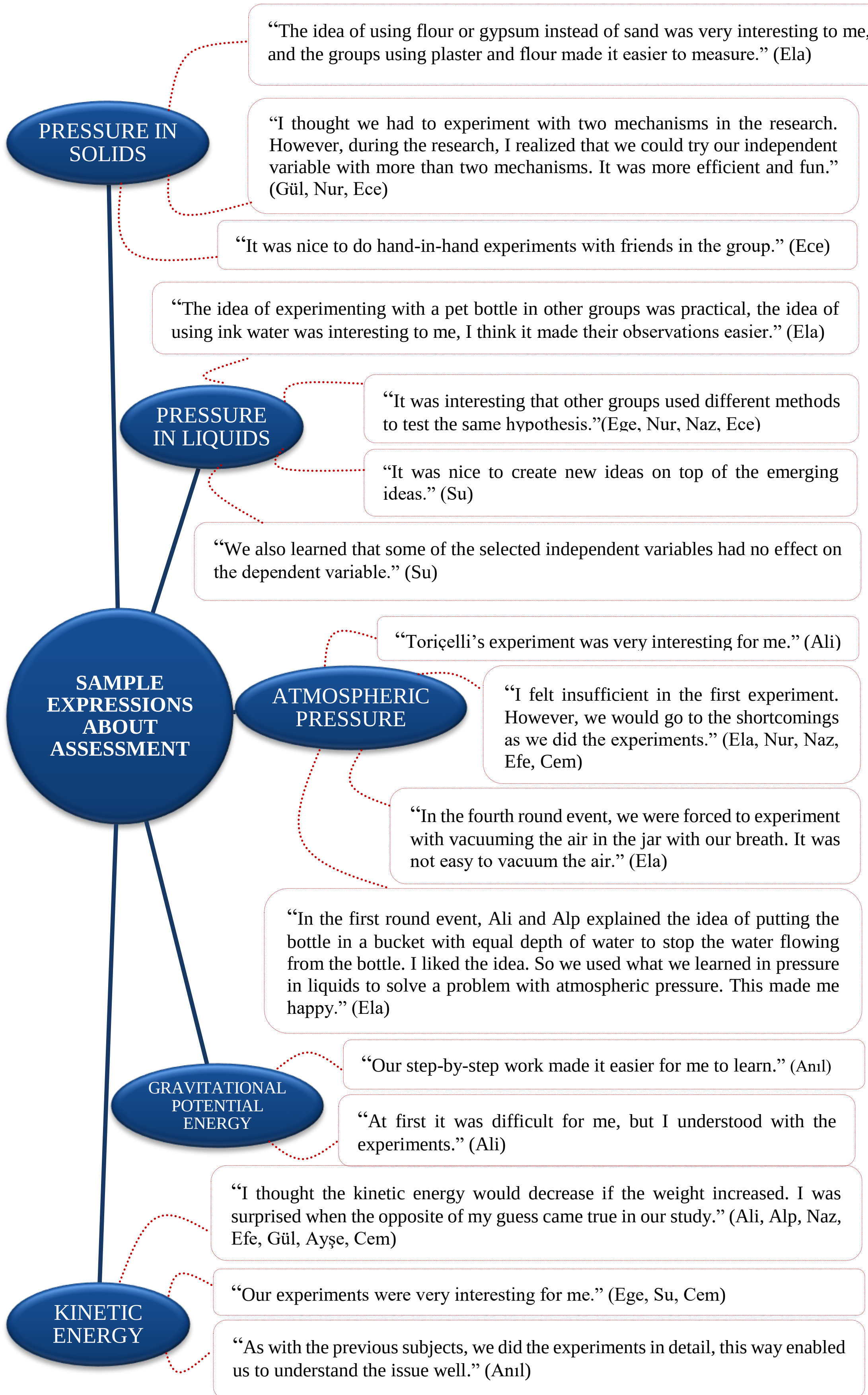
Model 5. Students' awareness about applied methods



Model 6. Students' awareness of materials used



Model 7. Students’ awareness about learning process



Model 8. Students' awareness of assessment

In the content analysis of the qualitative data, despite the fact that students' expressions were mostly gathered in the beginning of the IBL process to make students feel inadequate, the expressions of feeling inadequate as the learning process progressed were left, and they were replaced by expressions about not feeling inadequate. At the beginning of the IBL process, students' expressions of feeling inadequacy generally included the following statements: "I was unfamiliar with constructing a controlled experiment", "I was upset when my hypotheses were wrong" and "I was forced at first".

It was discovered that students mostly formed directional hypotheses during the IBL process and that in the first experiments of the IBL process, they were surprised and upset when the experiments carried out by the students resulted in a different direction from the hypothesis they established. The students expressed these feelings during the semi-structured interviews with the following words: "It upset me when my hypotheses were wrong". This situation means that the students who use this voice expect to see that the hypothesis established at the beginning of the IBL process should be supported as a result of their experiments. However, in the later weeks of the IBL process, it was seen that the students accepted this situation when the results of the experiment were different from their hypotheses. The students expressed this as follows: "The fact that our hypothesis results in a mistake and that the hypothesis we have established turns out to be in the opposite direction also enable us to learn".

The student's voices "I was forced at first because I did not know the issue", used at the beginning of the IBL process, could be interpreted as follows: "Students were unaware that information can be accessed using scientific inquiry". Over time, this idea gave way to the following statement presented in content analysis models: "I learned the subject by doing scientific inquiries".

It was discovered that the students' voices "I thought we had to experiment with two mechanisms in research. However, during the research, I realized that we could try our independent variable with more than two mechanisms. It was more efficient and fun", used at the beginning of the IBL process, shows that the students had a misconception about the statement "In order to conduct scientific inquiry, it is necessary to establish two different mechanisms in terms of independent variables". Also, it has seen that students develop an idea suitable for scientific inquiry by applying in the process.

4. Discussion and conclusion

Although there is no statistically significant difference between the basic SPS, high level SPS, and general SPS levels before the application process of the experimental and control groups, there has been a significant difference between basic SPS, high level SPS, and general SPS levels of the experimental and control groups in favor of the experimental group after the IBL process. Additionally, a statistically significant difference has been found between the pre-test and post-test scores of the basic SPS, high level SPS, and general SPS levels of the experimental group students in favor of the post-tests. This shows that the IBL approach has an effect on the basic SPS, high level SPS, and general SPS levels. However, it should be noted that there is no statistically significant difference between the pre-test and post-test scores of the control group of the basic SPS, high level SPS, and general SPS levels. Therefore, it has been seen that the teaching process in the control group could not improve the students' basic SPS, high level SPS, and general SPS levels at a level that would make a statistically significant difference. The results obtained in the literature are similar to the various studies on the effects of the IBL approach on different variables. In the studies conducted by Tatar (2006), Kuhn and Pease (2008), Wilson et al. (2010), Çeliksöz (2012), Büyükdokumacı (2012), Duran (2014), Bunterm et al. (2014), Kaya and Yılmaz (2016), Yıldırım and Altan (2017), and van Uum et al. (2017) with different age groups, the effect of the IBL approach on SPS is revealed. It is stated that students have made significant progress in understanding the goals of questioning over time, defining questions, explaining their ideas, making controlled comparisons, interpreting the increasingly complex data, supporting claims and making validated predictions, and using the scientific method as necessary to manage their own learning processes. In this respect, the findings and results obtained from the analysis of quantitative and qualitative data in this study are similar to those mentioned in this study.

According to the results obtained in the analysis of the qualitative data of the research, the students' thoughts regarding the teaching process carried out in line with the IBL approach are as follows:

- They think that they have realized a more detailed learning by scientific inquiry,
- They think that they will be able to learn topics they do not know by performing similar scientific inquiry activities,
- They have seen that they can easily learn the subjects they think are too difficult,
- As a result of the experiment, they have realized that the correct and incorrect results of their hypotheses provide learning,
- They think that the use of more than two mechanism in experiments to test a hypothesis provides better results,
- They have realized that there are many different mechanisms that can be established to test the same hypothesis, and they find it interesting,
- They have realized that they can use different materials in similar experimental mechanism to test the same hypothesis,
- They have realized that non-affective variables can be detected such as independent variables that affect a dependent variable by using scientific inquiry,
- They have realized that in order to solve any problem on another topic, they can use the information that they have learned on a previous subject,
- They have been happy to see what they can achieve during the IBL process,
- They have realized that they can compare multiple methods used for the same research subject and draw conclusions,
- They have been disposed to use the scientific inquiry method again so as to do new researches in daily life,
- Initially they had difficulty in identifying the problem, establishing hypothesis, determining and controlling variables, planning experiments in accordance with the variables and hypotheses, and even they could not; however, they have realized that they have accomplished them easily in the following process, that is, they are aware of the progress they have made in the IBL process,
- They found the lesson activities funny and interesting,
- They have been happy when their stages in experiments result in learning,
- Although they thought "I cannot carry out the experiments about scientific inquiry" and then they were surprised and glad when they saw what they could achieve,
- They are aware that the feeling of fear of taking responsibility for learning is replaced by the desire to learn,
- In each new experiment they had the following excitement: "I wonder what other groups will try, how to do the experiment",
- They have realized that more than one method can be applied to solve a problem and that more than one can be correct.

In addition to the student expressions, based on student worksheets completed by students during the process, and the teacher observations, the students carried out the following points:

- They performed in IBL process gladly,
- All group members, even including academically disadvantaged students, performed the experiments eagerly, took part in group works with interest, curiosity, and enthusiasm,

- When they saw that the predictions in their hypotheses were wrong as a result of experiments, they learned with surprise,
- Although they were content with just two mechanisms at the beginning to try their hypotheses, they started to use more and more as the process progressed,
- Although they used simple tables or data logging methods to save the initial data, they have used more qualified data logging methods in the forthcoming days,
- Although they never or rarely use graphical representation of the data they recorded at the beginning, they have used different graphical forms more consciously in the forthcoming days.

In the literature, in the research conducted by Chang and Moa (1999), Duran (2014), Yaşar and Duban (2009), it is emphasized that in the process of IBL, the students found the lessons more enjoyable, they are more interested in the course and they have learned more easily and that the effect of the IBL approach on the attitude and motivation towards learning the science course. In this respect, the findings and the results obtained from the analysis of the qualitative data of this research are similar to the researches mentioned. In the current study, it is found that students had less difficulty in expressing research topics with problem sentence in the second part of pressure in solids and that the students no longer have difficulty in creating a problem statement about pressure in liquids. Similarly, it is observed that in the IBL process, students have been able to detect and correct faulty practices that could affect their results without the need of teacher guidance during the scientific inquiry experiments. Moreover, over time, it is observed that students could direct their own learning process and apply the scientific method properly. This may have been due to the students becoming familiar with such scientific inquiry over time. In this regard, the IBL process was carried out with an in-depth teacher guidance in the first days; however, teacher guidance was gradually reduced by considering the progress of the students. Alleviating the level of teacher guidance that students need in the process is similar to the research conducted by van Uum et al. (2017).

5. Suggestions

In line with the results obtained in the study, the following suggestions were created:

- In order to develop the students' scientific process skills in all sub-dimensions, students should be provided with learning environments in which the IBL approach can be used actively by applying these skills as a scientist. Providing these skills, especially during the process of the development of abstract thinking skills, will enable them to acquire skills that they can use throughout their lives.
- At the application stage of the research, it was observed that the students with relatively low skills in the experimental group were closely interested in learning activities, they made efforts to participate in the studies and they participated in the learning process with interest and curiosity. In this regard, the contribution of the IBL approach to collaborative learning environments should be considered not only to academically successful students, but also to students with relatively lower skills.

As presented in the review of the literature, new studies can be conducted in order to increase the quantity of research on the application of the IBL approach in science classes and especially in secondary school students.

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References

Aydoğdu, B., Tatar, N., Yıldız, E., & Buldur, S. (2012). The science process skills scale development for elementary school students. *Journal of Theoretical Educational Science*, *5*(3), 292-311.

Bernal, J. D. (2011). *The social function of science.* (T. Ok, Int.) İstanbul: Evrensel Publishing. (Published in the original study: 1939)

Bunterm, T., Lee, K., Ng Lan Kong, J., Srikoon, S., Vangpoomyai, P., Rattanavongsa, J., & Rachahoon, G. (2014). Do different levels of ınquiry lead to different learning outcomes? A comparison between guided and structured inquiry. *International Journal of Science Education*, *36*(12), 1937-1959. https://doi.org/10.1080/09500693.2014.886347

Büyükdokumacı, H. (2012). *Effects of problem based learning on learning products in science and technology lesson for elementary 8th grade*. Master's Thesis, Pamukkale University.

Büyüköztürk, Ş. (2015). *Data analysis handbook for social sciences*. Ankara: Pegem Academy Publishing, 21 st edition.

Bybee, R. W. (2006). Scientific inquiry and science teaching. In L. B. Flick & N. G. Lederman (Eds.), *Scientific inquiry and nature of science: Implications for teaching, learning, and teacher education* (pp. 1-15). Netherlands: Springer Publications.

Chang, C. Y., & Mao, S. L. (1999). Comparison of Taiwan science students' outcomes with inquiry-group versus traditional instruction. *Journal of Educational Research*, *92*(6), 340-349. https://doi.org/10.1080/00220679909597617

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches* (2nd Ed.). Thousand Oaks, CA: Sage.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research* (p. 1-19). Thousand Oaks, CA: Sage Publications, 2nd edition.

Çeliksöz, M. (2012). *Effects of different levels of inquisitive-research-based teaching methods on the success, attitude, scientific process skills and knowledge permanence of primary school students*. Master's Thesis, Trakya University.

Dell'Olio, J. M., & Donk, T. (2007). *Models of teaching*. Thousand Oaks, CA: Sage Publications.

Duban, N. (2014). Inquiry-based learning. In Ş. S. Anagün & N. Duban (Ed.), *Teaching science* (pp. 221-240). Ankara: Anı Publishing.

Duran, M. (2014). *The effect of research-based learning approach on the level of conceptual understanding of the unit of granular structure of matter and some learning outcomes*. Phd Thesis, Gazi University.

Filippi, A., & Agarwal, D. (2017). Teachers from instructors to designers of inquiry-based science, technology, engineering and mathematics education: How effective inquiry-based science education implementation can result in innovative teachers and students. *Science Education International*, *28*(4), 258-270.

Jesus, H. P., Souza, F. N., Teixeira-Dias, J. J., & Watts, M. (2005). Organising the chemistry of question-based learning: A case study. *Research in Science & Technological Education*, *23*(2), 179-193. https://doi.org/10.1080/02635140500266419

Kaya, G., & Yılmaz, S. (2016). Impact of open interrogation-based learning on students' success and development of scientific process skills. *Journal of Hacettepe University Faculty of Education, 31*(2), 300-318. https://doi.org/10.16986/HUJE.2016016811

Kuhn, D. & Pease, M. (2008) What needs to develop in the development of inquiry skills? *Cognition and Instruction, 26*(4), 512-559. https://doi.org/10.1080/07370000802391745

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*(4), 331-359.

Lederman, N. G., Abell, S. K., & Akerson, V. (2008). Student's knowledge and skill with inquiry. In E. Abrams, S. A. Southerland & P. Silva (Eds.), *Inquiry in the classroom: Realities and opportunities* (pp. 3-35). USA: IAP–Information Age Publishing.

Metz, K. E. (2004). Children's understanding of scientific inquiry: Their conceptualization of uncertainty in investigations of their own design. *Cognition and Instruction*, *22*(2), 219-290. https://doi.org/10.1207/s1532690xci2202_3

MoNE (2013). *Science course curriculum of primary schools.* Ankara: MoNE Publishing.

MoNE (2017). *Science curriculum (3, 4, 5, 6, 7 and 8. Classes).* Taken from https://ttkb.meb.gov.tr/www/ogretim-programlari/icerik/72.

Morse, J. M. (2003). Principles of mixed methods and multimethod research design. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social & behavioral research* (pp. 189-208). Thousand Oaks, CA: Sage Publications.

National Research Council (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council (2000). *How people learn. Brain, mind, experience, and school*. Washington, DC: National Academy Press.

Sahranç, Ü. (2011). Basic learning environments: Family-school-class. In İ. Yıldırım (Ed.), *Educational psychology* (pp. 323-348). Ankara: Anı Publishing, 3rd edition.

Şahan, H. H., Uyangör, N., & Işıtan, S. (2012). Learning-teaching strategies and models. In B. Oral (Ed.), *Learning-teaching theories and approaches* (pp. 283-408). Ankara: Pegem Academy Publishing, 2 nd edition.

Tatar, N. (2006). *The impact of research-based learning approach in primary science education on scientific process skills, academic success and attitude*. PhD Thesis, Gazi University.

Türkdoğan, O. (2000). *Bilimsel araştırma metodolojisi* [Scientific research methodology]. İstanbul: Timaş Yayınları, 3. baskı.

Yaşar, Ş., & Duban, N. (2009). Student opinions on questioning-based learning approach. *Primary Online, 8*(2), 457-475. [Online]: http://ilkogretim-online.org.tr.

Yıldırım, M., & Türker Altan, S. (2017). The impact of research and inquiry-based learning approach on the scientific process skills of primary school students. *Journal of the Institute of Social Sciences of Mustafa Kemal University, 14*(38), 71-89.

Yıldız, E. (2008). *Effects of mastery in teaching based on conceptual change using the 5E model: an application for 7th-class force and movement unit*. Phd Thesis, Dokuz Eylül University.

van Uum, M. S. J., Verhoeff, R. P., & Peeters, M. (2017). Inquirybased science education: Scaffolding pupils' self-directed learning in open inquiry. *International Journal of Science Education*, *39*(18), 2461-2481. https://doi.org/10.1080/09500693.2017.1388940

Varelas, M. (1996). Between theory and data in a seventh-grade science class. *Journal of Research in Science Teaching*, *33*(3), 229-263.

Ward, H. (2007). *Using their brains in science: ideas for children aged 5 to 14.* London: Paul Chapman Publishing.

Wilson, C. D., Taylor, J. A., Kowalski, S. M., & Carlson, J. (2010). The relative effects and equity of inquiry-based and commonplace science teaching on students' knowledge, reasoning, and argumentation. *Journal of Research in Science Teaching*, *47*(3), 276-301.

Zandvliet, D. B. (2013). Environmental learning. In D. B. Zandvlient (Ed.), *The ecology of school* (s. 1-18). The Netherlands: Sense Publishers.