

# Laboratory as an Instrument in Improving the Scientific Reasoning Skills of Pre-Service Science Teachers with Different Cognitive Styles<sup>‡</sup>

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**Abstract:** *In this study, it was aimed to investigate the effects of guided inquiry learning approach-based laboratory applications on the scientific reasoning skills of pre-service science teachers with different cognitive styles. Additionally, the opinions of pre-service science teachers with different cognitive styles about the effects of the application carried out in the study on the improvement of their scientific reasoning skills were also examined. The sample consisted of five pre-service science teachers studying at a state university in the west of Turkey. In the study, the partially mixed sequential dominant status design, which is a mixed-method research design, was used. The scientific reasoning skills of the participants were determined by using the Classroom Test of Formal Reasoning, and their cognitive styles were identified with the Group Embedded Figures Test. The opinions of the participants were taken through focus group interviews held after the application. As a result of the analysis, it was observed that the participants with field-dependent and field-intermediate cognitive styles achieved more targeted outcomes compared to those with field-independent cognitive styles. The potential relationship of this finding to the use of the guided inquiry learning approach and the hypothetico-deductive reasoning cycle during the applications was analyzed in terms of the concept of information processing, and recommendations were made for researchers.*

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## **Introduction**

Scientific reasoning skills (Gray, 2016), which are among 21st century skills, have long been at the focus of developmental psychology, education psychology, and science education research (Cheng et al., 2018; Shayer & Adey, 1992). Since it would be impossible to have individuals encounter all potential problem situations in practice, it could be possible to adapt to the quickly changing world if individuals are trained with the ability to solve the problems they encounter by using and evaluating the information they gain through scientific methods and understand the information production process, in other words, have advanced reasoning abilities (Osborne, 2013; Schiefer et al., 2019). If success in science is defined as the ability to explain natural phenomena by creating hypotheses and testing them, one of the most important predictors of scientific success is scientific reasoning skills (Lawson, 1983).

It is seen that scientific reasoning skills, which have been demonstrated to have a positive contribution to students' success in science (Vadappally, 2014), can be developed through educational activities (Daempfle, 2006; Engelmann et al., 2016; Jensen & Lawson, 2011; Marušić-Sliško, 2011; Shayer & Adey, 1992). According to many studies, inquiry-based applications make a positive contribution to students' scientific reasoning skills (Blumer & Beck, 2019; Daempfle, 2006; Klahr et al., 2019; Schiefer et al., 2019; Stender et al., 2018; Van der Graaf et al., 2019; Yulianti et al., 2018; Yulianti et al., 2020). One of the points where inquiry-based applications and scientific reasoning skills intersect in science education is the laboratory.

Laboratory applications, which contribute significantly to the development of scientific reasoning skills, have long had a pivotal role in science education (Hofstein; et al., 2019; Lunetta et al., 2007). Reform movements in science education realized from the past to the present have manifested themselves in laboratory applications as well, and over time, rather than confirmatory forms of laboratory applications, laboratory applications in which investigation and inquiry are more pronounced have been emphasized (National Research Council [NRC], 2013). Although studies carried out on the effectiveness of inquiry-based laboratory applications have mostly yielded positive results (Beck et al., 2014), there are also other studies which demonstrated that the effects of inquiry-based learning in laboratory classes may not always be uniform for all students. The individual differences of students such as gender, race, ethnic origin, and age lead to differences in their performance (Blumer & Beck, 2019). One of the individual differences on which the most research has been conducted in the literature is cognitive styles. Cronbach and Snow (1977) defined cognitive styles as an information processing strategy that an individual prefers while organizing everything they see, remember, and think about. Although there are many classifications

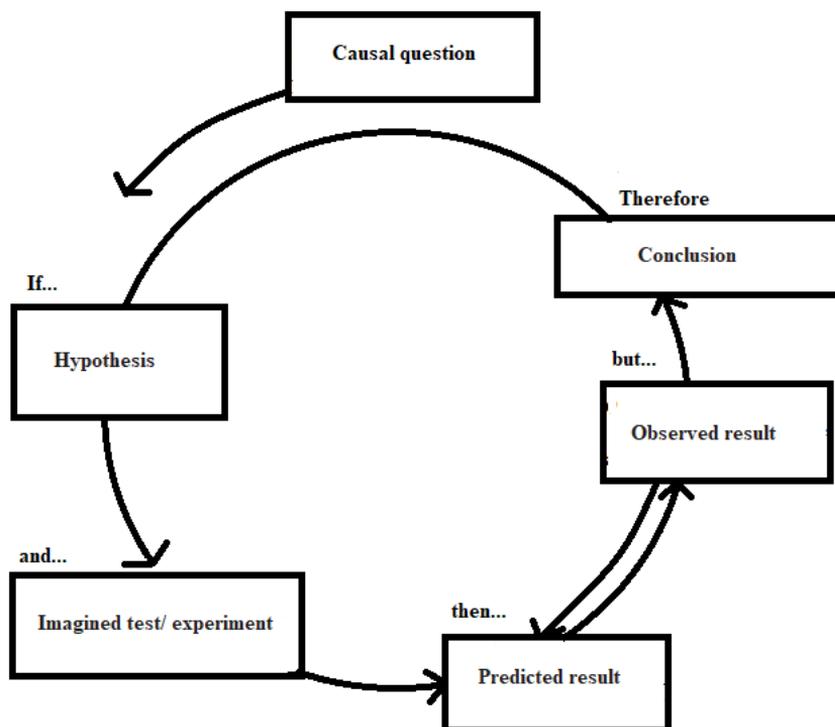
regarding cognitive styles, field-dependent/field-independent cognitive styles are stated as the cognitive style dimensions which have a wide range of application in educational problems (Witkin et al., 1977). It has been stated in research conducted on field-dependent/field-independent cognitive styles that this construct is one of the most significant predictors of academic success, and field-independent individuals are usually more successful than field-dependent individuals (Ates & Cataloglu, 2007; Cataloglu & Ates, 2014; Idika, 2017; Morris et al., 2019). In the relevant literature, it is seen that this construct has been significantly associated with not only the student's success in science but also their scientific reasoning skills (Ahmar et al., 2018; Stamovlasis & Papageorgiou, 2012).

## **Literature Review**

### ***Scientific Reasoning Skills***

Scientific reasoning skills are handled within the framework of the concept of cognitive development. The theory which is acknowledged the most in the field of education in relation to cognitive development is Piaget's Cognitive Development Theory. In the theory, the development of reasoning abilities in children and adolescents has also been defined and analysed (Inhelder & Piaget, 1958). The characteristics of the concrete and formal operations included in the theory among developmental stages have particular importance for science teachers and pre-service science teachers. The groundwork of thinking and reasoning is laid in the concrete operational stage. On the other hand, abstract thinking and reasoning about unseen and unfamiliar contexts in individuals begin in the formal operational stage. In this context, hypothetico-deductive reasoning is a way of reasoning observed in individuals who are in the formal operational stage (Lawson, 2000; Melnick, 1974).

Lawson (2000) defined the reasoning process that individuals must have in the formal operational stage as a construct in which a hypothesis testing process is widely used through deduction by the control of variables, as well as proportional, combinational, correlational and hypothetical-deductive reasoning skills. Considering the steps required for the realization of the hypothetico-deductive reasoning cycle proposed by Lawson et al. (2000), it is seen that they overlap with the eight science practices (asking questions related to science, identifying the problems, using and developing models, planning and researching, analysing and interpreting the data, using mathematics, making explanations, designing solutions, discussing based on evidence, evaluating the information) included in the first dimension of the New Generation Science Standards prepared by the National Research Council (NRC, 2013) in the US. Similarly, in the inquiry research cycle proposed by White and Frederiksen (1998), as well, there are interrelated and



**Figure 1. Hypothetico-Deductive Reasoning Cycle**

Note. From *Science Teaching and the Development of Thinking* (p.115), Lawson, A. E., 1995, Wadsworth/Thompson Learning.

repetitive stages of asking questions, establishing a hypothesis, researching, analysing, and synthesizing. From this perspective, it is seen that hypothetico-deductive reasoning is an essential component in the inquiry research cycle (Pedaste et al., 2015; White & Frederiksen, 1998). For this reason, the hypothetico-deductive reasoning cycle suggested by Lawson (2000) to be used in inquiry activities was included in the experiment process. This cycle is presented in **Figure 1**.

### ***Guided Inquiry Learning***

The word “inquiry” is used with two different meanings in the report of the National Research Council that establishes the standards of science education (Bybee, 2000). The first of these is the creation of conceptual knowledge that ensures the student understands of the phenomena they encounter in daily life. The second meaning refers to the development of the student’s high-level thinking skills such as asking questions, critical thinking, problem

**Table 1. Levels of Inquiry.**

Levels	Source of the Research Questions	Source of Data Collection Methods	Source of Interpretations of Results
Level 0: Verification	Given by teacher	Given by teacher	Given by teacher
Level 1: Structured	Given by teacher	Given by teacher	Open to student
Level 2: Guided	Given by teacher	Open to student	Open to student
Level 3: Open	Open to student	Open to student	Open to student

solving, metacognitive, and argumentation skills (Hofstein & Kind, 2012). In this context, many science educators and curriculum developers argue that students must apply scientific methods and answer research questions by producing and analysing data to not only comprehend science concepts but also gain scientific reasoning skills (Abd-El-Khalick et al., 2004). In this context, when science laboratory applications are carried out based on inquiry, they ensure the development of metacognitive thinking skills and thus contribute to conceptual understanding (Hofstein, 2016). Inquiry-based learning in science education refers to an approach in which students actively use scientific methods to be able to answer research questions (Bell et al., 2005). Bell et al. (2005) stated that inquiry-based learning can be applied on four different levels by considering the amount of guidance provided by the teacher (**Table 1**).

In the meta-analysis and review studies on inquiry-based learning, which can be applied on four different levels, presented in **Table 1**, it is seen that the effects of inquiry-based learning activities on the first and particularly the second levels, where a certain amount of guidance is provided to students, on the students' learning outcomes are more positive compared to these effects on third-level activities, where no guidance is provided (Alfieri et al., 2011; Bruder & Prescott, 2013; Carolan et al., 2014; Lazonder & Harmsen, 2016; Minner et al., 2010; Yulanti et al., 2020). However, there are very few studies that support the positive effect of third-level activities where no guidance is provided on students' success in science. Therefore, the second-level inquiry-based learning approach was taken as the basis in this study.

## ***Cognitive Styles***

Cognitive styles are defined as a binary holistic construct which affects all activities of individuals and surpasses the limits of the human mind (Witkin et al., 1977). As a result of studies in this area, many cognitive style dimensions have been identified. Among the cognitive styles that have been identi-

fied so far, field-dependent/field-independent styles have been examined the most, and they are stated as the cognitive style dimension that has the widest range of application in educational problems (Evans et al., 2013; Witkin et al., 1977).

Field-independent individuals are affected less by external stimulants compared to field-dependent individuals in terms of analysing the complex structure of the area in which they are and being able to extract a certain element out of a complicated whole. While field-dependent individuals attach importance to external stimulants affecting their perceptions, it is not external stimulants but internal stimulants that are important for field-independent individuals (Jonassen & Grabowski, 1993). In operational terms, field-dependence/field-independence is defined as a construct that measures the individual's ability to differentiate a single figure from a complicated background. Differentiation is the ability to visually differentiate a piece from a complex whole. For this reason, field-dependent individuals are characterized by their perception of an area as a whole by ignoring the figures (Witkin et al., 1971). This perceptual and intellectual functioning leads to individual differences ranging from the analytical area approach to the holistic area approach.

As a result of many studies conducted in this field, it has been determined that the performance levels of field-dependent and field-independent students in learning activities vary. Field-dependent students show superior performance in comparison to field-independent students in activities in which group work and collaboration are required, the instructions are clearly provided, and previously learned information must be remembered. Field-independent students, on the other hand, display better performance compared to field-dependent students in terms of solving problems (especially mathematics), determining the significant aspects even if the information is poorly organized, and applying the learned information to different situations (Jonassen & Grabowski, 1993).

## ***The Present Study***

The changes experienced in the 21st century have led to changes in the roles expected from individuals. Accordingly, the education and equipment of teachers who will raise such students in terms of educating individuals in line with the requirements of the century become more important. For developing students' scientific reasoning skills, which are considered important in terms of the century we are in, it is needed to have teachers whose such abilities have developed. For this reason, for teachers to help students in terms of developing scientific reasoning skills, it is important for them to first improve themselves in this regard. Though there are many studies in the relevant literature that have demonstrated the positive contribution of guided in-

quiry learning approach-based laboratory (GILABL) applications to the development of the scientific reasoning skills of students, no study revealing the performance differences and/or similarities of pre-service science teachers with different cognitive styles in the application of this method was encountered. It is believed that determining this individual difference, which is highly important in terms of explaining the student's performance and examining the effects of guided inquiry learning approach-based laboratory applications on the development of scientific reasoning skills, will contribute to the education of pre-service science teachers in accordance with the needs of the century.

Consequently, it was deemed important in this study to determine how pre-service science teachers with different cognitive styles benefited from guided inquiry learning approach-based laboratory applications in terms of the development of their scientific reasoning skills. Additionally, to develop a better understanding of this form of utilization, the opinions of pre-service science teachers about the effects of the application in question on the development of their scientific reasoning skills were also received.

In this context, the research questions were as follows:

- (i) Do GILABL applications used in the science laboratory class have any effects on the scientific reasoning skills of pre-service science teachers? (RQ1)
- (ii) Is there a difference between the scientific reasoning skills of pre-service science teachers with different cognitive styles before and after the experimental application? (RQ2)
- (iii) What are the opinions of pre-service science teachers with different cognitive styles about the effects of GILABL applications on the development of their scientific reasoning skills? (RQ3)

## **Method**

In the study, in which quantitative and qualitative research methods were used to find answers to the research questions, the mixed-method research design was employed. As the quantitative data were collected before the qualitative data, and the quantitative data were more dominant, this study included the partially mixed sequential dominant status design, which is a mixed-method design (Leech & Onwuegbuze, 2009). In the first and quantitative part of the study, the effects of GILABL applied to the pre-service science teachers studying science teaching on their scientific reasoning skills and the variation of these effects based on cognitive styles were investigated. In the second and qualitative part of the study, the opinions of pre-service science teachers about the experimental application in question were analyzed through focus group discussions. In the quantitative part of the study, the 'static group pretest-posttest design' (Fraenkel et al., 2011) used in ex-

**Table 2. Participant Profile.**

Participant Codes	Gender (Female/Male)	GPA	Cognitive Style (Field Independent/Field Intermediate/Field Dependent)
S1	Male	2.96	Field-independent (FID)
S2	Male	2.86	Field-dependent (FD)
S3	Female	3.22	Field-intermediate (FINT)
S4	Female	3.37	Field-intermediate (FINT)
S5	Female	2.80	Field-intermediate (FINT)

perimental research was employed, while the case study design was used in the qualitative part.

### ***Sample***

The sample consisted of third-year students studying in the science teaching program at the education faculty of a state university located in the west of Turkey in the fall semester of the academic year of 2020-2021. The study was designed within the scope of the Science Teaching Laboratory Applications 1 course and carried out with the voluntary participation of five pre-service science teachers. Prior to the application, all pre-service science teachers to be included in the study were informed about the purpose and process of the study, and the consent of each participant was taken. The classes could not be held face-to-face due to the ongoing COVID-19 pandemic, and they were provided online via distance education. Three of the participants were female, and two were male. To ensure confidentiality, the real names of the participants were not disclosed in the coding and reporting stages of the qualitative data. The participants were given codes from S1 to S5, each code representing one participant. Information about the genders, grade point averages (GPA), and cognitive styles of the participants is given in **Table 2**.

### ***Data Collection Tools***

In the study, the Group Embedded Figures Test (GEFT) developed by Witkin et al. (1971) and adapted to Turkish by Cakan (2003) was used to determine the participants' field-dependent/field-independent cognitive styles. GEFT, in which respondents are asked to find the desired figure out of a complex context, is composed of 18 questions. A certain pattern is followed in determining cognitive styles according to the scores the respondents obtain from the test (Dwyer & Moore, 1992). The Cronbach's alpha internal consistency coefficient of the Turkish adaptation of the test was reported to

be 0.82 (Cakan, 2013). Special permission was obtained from MindGarden to administer the test developed by Witkin et al. (1971). Information on the permit can be found in supplementary material 1.

In the study, the Classroom Test of Formal Reasoning was employed to measure the participants' scientific reasoning skills (Lawson et al., 2000). The test consists of 13 two-step questions which require conservation, control of variables, proportional reasoning, correlation reasoning, probability reasoning, combinational reasoning, and hypothetical-deductive reasoning. The administration of the test takes 40 minutes. The test was adapted to Turkish by Ates and Cataloglu (2007), and the Cronbach's alpha internal consistency coefficient of the test was calculated as 0.70.

In this study, as the qualitative data collection tool, focus group interview questions were used to identify the opinions of the participants about the GILABL applications. These interview questions were prepared by the researchers, and they had a semi-structured format consisting of eight main questions and probing questions. The semi-structured interview form was prepared by considering the literature on the opinions of pre-service science teachers regarding the use of laboratory-based methods (Ceylan et al., 2019; Evren-Yapicioglu & Yurttas-Kumlu, 2017). The focus group interview questions were evaluated by an expert in science education, and the final version was created.

## ***Data Analysis***

In the analysis of the quantitative data of the study, descriptive and predictive statistical methods were employed. In this context, descriptive analyses and Wilcoxon Signed-Rank Test were used for the quantitative data, while descriptive analyses were used in the analysis of the qualitative data. In the coding of the qualitative data, common coding was continued until there was 100% agreement between the researchers. For this reason, a percentage of agreement was not calculated separately.

## ***Implementation***

In this study, both data collection and application processes were carried out through the Microsoft Teams program. The quantitative data in the study were collected in live lecture sessions with the participants and researchers. In this process, the participants were asked to have their cameras turned on, and the necessary documents were uploaded to the system right after the application. In the process of collecting qualitative data, focus group interviews were conducted through the same program.

Within the scope of the study, the content of the Science Teaching Laboratory Applications 1 course was designed in accordance with the use of GILABL applications where the hypothetico-deductive reasoning cycle

was used, and content for 12 weeks was prepared. The course in question is one of the compulsory courses included in the science teaching program in Turkey. While preparing the experiments included in the content, attention was paid to ensure that the experiments were practical enough to be conducted individually at home by using simple materials, as the courses were being held via distance education due to the ongoing COVID-19 pandemic period.

Each experiment was completed within a period of two weeks. In the first week, a problem scenario regarding the concept to be dealt with was provided, and the participants were asked to form their hypotheses for the solution of the problem, choose one of the hypotheses, and design an experiment for testing the hypothesis. In the second week, the experiments designed for testing the hypothesis were conducted, and the participants were expected to reach a judgement by comparing the results they envisaged with the actual experimental results. Following this stage, the concept in question was explained and associated with daily life by the instructor of the course, and the class was finalized. The reports prepared by the participants before and after the experiment were compared by the researchers, and the necessary feedback was given. After corrections were made by the participants, the reports were examined again. The process that was followed in the implementation is presented in **Figure 2**, and a basic process and example scenario of experimental applications can be found in supplementary material 2.

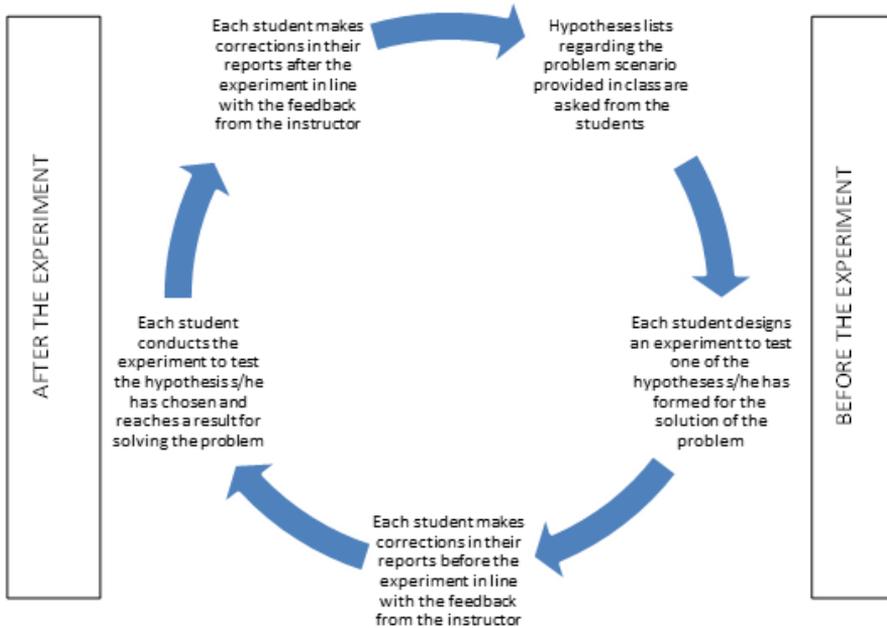
## ***Ethical Considerations***

Ethical approval was granted by Institutional Ethical Committee on 15 September, 2020. Additionally, all potential participants were informed about the study, and those who voluntarily agreed to participate were included. Besides, codes were assigned to the participants in the place of their names to anonymize their identities.

## **Results**

### ***Results for RQ1***

For RQ1, the data obtained using the Classroom Test of Formal Reasoning that was applied before and after the application to determine the change in the scientific reasoning skills of the participants as a result of the application were compared. As the collected data did not have a normal distribution, Wilcoxon Signed-Rank test was employed. The results revealed that the posttest scores of the participants were significantly higher (Mdn = 12,  $n = 5$ ) compared to their pretest scores (Mdn = 9,  $n = 5$ ),  $z = -2.04$ ,  $p = 0.04$ , with a large effect size,  $r = 0.93$ .



**Figure 2. The Process Followed for Each Experiment.**

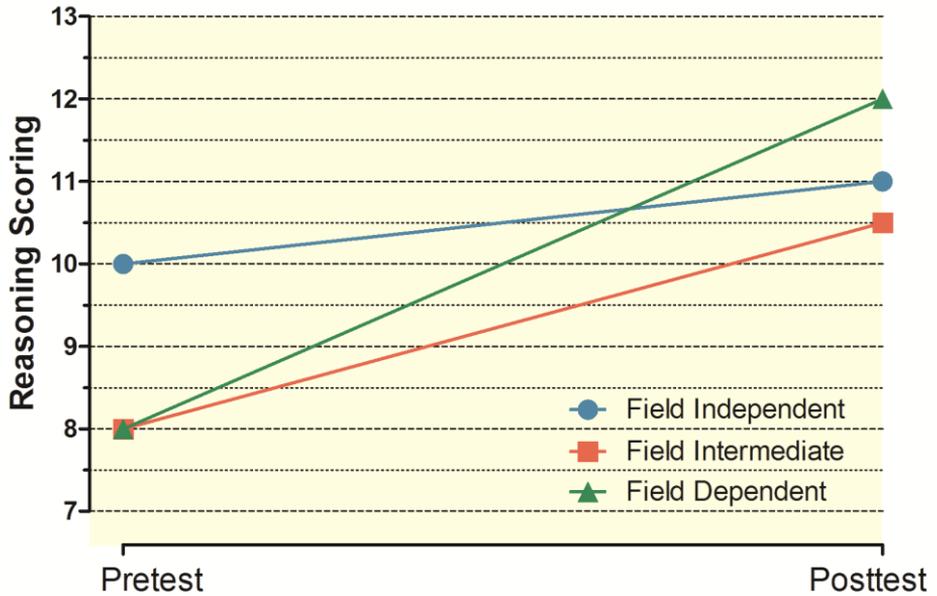
**Table 3. Descriptive Statistics of the Classroom Test of Formal Reasoning Results According to Cognitive Styles.**

Group	N	Mean <sub>pretest</sub>	Mean <sub>posttest</sub>
Field-independent	1	10.0	11.0
Field-intermediate	3	8.0	10.3
Field-dependent	1	8.0	12.0

## ***Results for RQ2***

For RQ2, the descriptive statistics of the results of the participants in the Classroom Test of Formal Reasoning before and after the application were calculated, and the results are presented in **Table 3**.

As seen in **Table 3**, while the mean test score of the participants with the field-intermediate cognitive style was higher before the application (mean = 10.0), the mean score of the participants with the field-dependent cognitive style was higher after the application (mean = 12.0). Another inter-



**Figure 3. Pretest-Posttest Classroom Test of Formal Reasoning Scores According to Cognitive Styles.**

esting point that draws attention in **Table 2** was that while a 4-point increase was observed in the mean test score of the participants with the field-dependent cognitive style after the application, only a 1-point increase was seen in the mean score of the participants with the field-independent cognitive style. The chart regarding the results is presented in **Figure 3**.

### ***Results for RQ3***

The opinions of the participants about the use of the GILABL applications were coded under the themes of their effects on the development of scientific reasoning skills with the headings of probability and combinational reasoning, correlational reasoning, hypothetical-deductive reasoning, and controlling of variables, and the results are presented below.

### ***Contribution to Probability and Combinational Reasoning Skills***

The point that was emphasized the most by the participants regarding the use of the GILABL applications was that the technique that was applied contributed to their understanding that they could approach events from different

perspectives. All participants' field-dependent and field-intermediate cognitive styles expressed that as a result of the application, they saw that there was not a single cause of events, but there might be other causes, and in other words, they could systematically think of all possible relations regarding an event or a situation. One participant with the field-dependent cognitive style stated that the requirement of writing at least three hypotheses to solve the problem situation in the provided scenario developed this ability:

*Professor, for example, you know, there is the part that required writing three hypotheses. The number being three is also very important; if it were only one, we would write one and leave it there, but when it is three, we are supposed to think more. In the experiment regarding fluid pressure, what I did was to think that we were on another planet. Yes, it is impossible to be there, but we had to write this up. (#S2/FD)*

The participants with field-intermediate cognitive styles expressed that thanks to the experiment, they could now approach events from different perspectives, and they became more inquisitive:

*...thanks to the experiments we conducted, I now approach an event differently and in an inquisitive manner; therefore, my scientific reasoning skills have been improved. (#S5/FINT)*

## *Contribution to Correlational Reasoning Skills*

One of the points that the participants mentioned regarding the use of the GILABL applications was that this technique contributed to their thinking about what type of relations existed between events and situations and whether they were connected or not. In this context, one participant with a field-intermediate cognitive style reported that the applications developed their abilities regarding the correlation of one variable with another:

*... I look at things more critically and inquisitively, I can see the differences more clearly. I used to look at things aimlessly, but now, I started to look at life more scientifically. (#S5/FINT)*

One participant with the field-independent cognitive style expressed that their correlational thinking ability which they already had turned into a conscious action thanks to the techniques applied. In other words, their mind gained a systematic of scientific thinking:

*...This course has been very beneficial for me; yes, I used to think about many things, you think about why sugar dissolves in tea, yes, you can say, because it is hot or something else, but I needed a sci-*

*entific reference. This course has been very efficient in terms of forming this reference. (#S1/FID)*

### *Contribution to Hypothetical-Deductive Reasoning*

Another point that the participants emphasized in regard to the use of the GILABL applications was that this technique contributed to them in terms of developing possible solution methods for an encountered problem that needs to be tested and trying these methods by using the solution methods systematically. In this context, the thinking processes and implementations of one participant with the field-dependent cognitive style in solving a problem that they faced were proof of the development of this ability. The participant thought that the implementation contributed to them becoming a solution-oriented individual:

*... I have become solution-oriented, too... For example, I have a bird, but it is too active, I cannot hold it though it has been with me for two years. I would give it feed every day, and it would scatter the feed all around. Finally, professor, I made a feedbox so that it could not spill the feed, and now the problem is solved. (#S2/FD)*

One participant with a field-intermediate cognitive style stated that the application helped them become a solution-oriented person who forms hypotheses in their mind about a problem they face and designs a thought-based experiment, thus indirectly expressing that their hypothetical thinking ability improved:

*... I think forming a hypothesis about an issue and creating a mental experiment developed my perspective. When faced with a problem, I immediately visualize the cycle we used, and I can design a mental experiment within my capacity. I design all steps of the mental experiment appropriately. Consequently, it helped me become a more solution-oriented person. (#S5/FINT)*

One participant with the field-independent cognitive style, on the other hand, stated that their inquiry ability that they previously used actively was now based more on scientific foundations, and their hypothetical-deductive reasoning, which they used to believe, was a difficult one, and improved as a result of the techniques applied:

*...As a result of this course, I came to understand that forming a hypothesis was a difficult task, but it became simpler when certain steps were followed, and I started to think more scientifically. I mean, I was actually thinking about some other things ... but there were always some things missing. Now, I both form hypotheses and*

*look at things from different perspectives. When I compare myself at the beginning of the semester to the present time, I am aware that I have improved in scientific terms. If you gave me a problem situation related to walking and asked me to form a hypothesis, I could form it. (#S1/FID)*

## *Contribution to the Skill of Controlling of Variables*

Another issue that the participants mentioned regarding the use of the GILABL applications was that the applied technique developed their thinking ability which includes identifying and controlling the variables by determining dependent and independent factors that affect a situation. In this context, one participants with the field-intermediate cognitive style expressed that their ability to identify and control the variables with which they used to have difficulties at the beginning of the application improved a lot in the process:

*...but it was difficult to design an experiment appropriate for my hypothesis. In this design, too, identifying the dependent and independent variables was challenging for me. (#S5/FINT)*

*Well, did you feel more competent later in identifying the dependent and independent variables? (#R1)*

*I definitely did. Before designing an experiment, I started to design it in accordance with the dependent and independent variables. When I moved to the other stages after identifying the independent variable, I was able to conduct a more accurate experiment. (#S5/FINT)*

## **Discussion and Conclusion**

In this study, first, the effects of GILABL applications on the scientific reasoning skills of the participants were investigated, and the impact of these effects on the scientific reasoning skills of the pre-service science teachers with different cognitive styles was examined. In the application carried out in this context, as a result of the analysis of both the quantitative and qualitative data, it was observed that the development in all participants' scientific reasoning skills was in a positive direction. This result of the study was consistent with the literature (Blumer & Beck, 2019; Daempfle, 2006; Engelmann et al., 2016; Jensen & Lawson, 2011; Marušić –Sliško, 2011; Shayer & Adey, 1992; Schiefer et al., 2019; Van der Graaf et al., 2019; Yulianti et al., 2020; Yulianti, et al., 2018). As the development of scientific reasoning skills is considered one of the objectives of science education (NRC, 2013), it has also been emphasized in many studies in the literature conducted for

the development of these abilities that some of the most effective practices are guided inquiry activities (Alfieri, et al., 2011; Bruder & Prescott; 2013; Carolan, et al., 2014; Lazonder & Harmsen, 2016; Minner et al., 2010; Yulanti, et al, 2020). This situation is believed to be in compliance with Piaget's cognitive development theory. This is because according to the theory, when students are exposed to teaching processes in which they can express their opinions, can make alternative explanations, and test their opinions, they will notice the missing points in their own reasoning processes and proceed in the direction of developing them. In classrooms where teaching is based on the presentation or transfer of knowledge, students cannot be motivated to solve their internal conflicts. Instead, they use their time to memorize the relevant knowledge. Jensen and Lawson (2011) placed students in three groups based on the scores they obtained from a scientific reasoning skills test to evaluate the effects of inquiry-based teaching (as opposed to conventional teaching) and the achievement of collaborative student groups with different compositions. In their study, the students with low scientific reasoning skills achieved more targeted outcomes in research and inquiry activities than the students with medium and high-level abilities. The students with low scores in the scientific reasoning skills test obtained significant increases in their scientific reasoning skill scores when the group was homogenous (the scores obtained from scientific reasoning skills being close), and the teaching method was based on research and inquiry. The researchers reported that the explanation for this situation was in Piaget's theory. The students achieved this result by taking the opportunity to self-organize without the guidance or direction of a more talented peer. Similar results were seen in the studies conducted by Beck and Blumer (2012) and Blumer and Beck (2019). In these studies, as well, the authors determined that the scientific reasoning skills of all students were developed with the guided inquiry laboratory method, but the highest gains were obtained by the students whose pretest scores were in the lowest quarter. The results obtained in this study were similar to the findings of the studies reported above. In this study, it was determined that the development of the scientific reasoning skills of the field-dependent participants with low scores from the scientific reasoning skills test was higher as a result of the guided inquiry techniques that were applied in comparison to their field-independent peers.

This effect of guided inquiry laboratory activities on the participants' scientific reasoning skills can also be explained in terms of their activities of information processing. In Pascual-Leone's (1970) Theory of Constructive Operators, the mental capacity of an individual is explained as a cognitive variable that defines their ability to process multiple phenomena or concepts simultaneously. In the theory, it is stated that individuals mostly do not use the entirety of their mental capacity, and individual differences such as some motivational variables and cognitive styles affect the utilization of this ca-

capacity (Pascual-Leone, 1970). Accordingly, when a student faces a problem situation or context in which relevant and irrelevant information about a topic is presented, the irrelevant piece of information uses a certain part of their mental capacity, and thus, less time is left for the processing of the relevant piece of information. In this case, field-independent students who can easily distinguish relevant information from irrelevant information have more functional mental capacity that they can use (Johnstone & Al-Naeme, 1991). In this theory, it is argued that the more complicated an activity is, the more the activity's mental demand is. Besides, the importance of the difference between the individual's mental capacity and the activity's mental demand is also emphasized. As a matter of fact, studies conducted on this field support these characteristics indicated in the theory. Previous studies have demonstrated that as the complexity of the activity (its mental demand) increases, the student's performance decreases, and small interventions made to the mental demand without changing the logical structure of the problem cause an increase in the student's performance (Danili & Reid, 2004; Niaz & Robinson, 1992; Tsaparlis & Angelopoulos, 2000). In fact, in the inquiry activities carried out by Kirschner et al. (2006), it was stated that as the teacher's guidance decreases, the activity's mental demand will increase, and therefore, the student's success will be negatively affected as more mental capacity will be needed. Moreover, the increase in guidance in the activities will reduce the load on mental capacity, and thus, there will be the opportunity to code new information and store it the long-term memory. These explanations are consistent with the results of this study. In this study, it was observed that the participants with the field-dependent and field-intermediate cognitive styles benefited more from the application compared to the students with the field-independent cognitive style. Accordingly, the much lower pretest scores of the field-dependent participants compared to the field-independent participants increased to a higher level than the scores of the field-independent participants as a result of the application. In the study, by both adopting the guided inquiry learning approach and using the hypothetico-deductive reasoning cycle, a contribution was made to the increase in the comprehensibility of the experiments by the field-dependent participants, and the activity's mental demand was reduced. It is thought that the integration of the hypothetico-deductive reasoning cycle into the experimental process for the field-dependent participants who needed the provided information to be organized contributed to their success in the guided inquiry activities positively. This is because in the relevant literature, researchers who have based their studies on students' cognitive styles and the characteristics of the activities related to mental demand have aimed to mitigate the effects of the field by removing unnecessary information from activities, and thus, they have observed increases in the performance levels of students (Danili & Reid, 2004; Tsaparlis & Angelopoulos, 2000).

## Recommendations, Limitations, and Implications

The results obtained in this study demonstrated the case which was expressed by Koran and Koran (1984) as ‘There is no one best educational treatment or environment suited to some general, average individual, but different individuals thrive in different environments suited to their own characteristics and needs’ (p. 795). In the study, the participants with the field-dependent cognitive style achieved higher success compared to their field-independent peers in a teaching design that was suitable for their cognitive styles and in an activity in which guidance was provided only on the research question and which had a high mental demand in this sense. Considering the results obtained in this study and the fact that the construct of cognitive style is in the high effect category in terms of predicting students’ success (Authors, 2020), it is seen that the concept of cognitive styles is a variable that should not be overlooked. Therefore, it is important that both educators and curriculum developers be aware of the cognitive styles that students have and design the learning environment and materials by considering the characteristics of students with different cognitive styles.

In the study, the effects of GILABL applications where the hypothetico-deductive reasoning cycle was used on the scientific reasoning skills of pre-service teachers with different cognitive styles were examined. However, the effects of whether this cycle was used in GILABL applications or not on students with different cognitive styles were not investigated. Although a positive contribution of the application was observed, especially for the participants with the field-dependent cognitive style, more experimental research is needed to reveal how effective the integration of the hypothetico-deductive reasoning cycle with guided inquiry activities is and to determine students’ opinions on the integration of this cycle with guided inquiry activities.

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## Appendix I

### Materials

**mind garden**  
Tools for positive transformation

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Menlo Park, CA 94025 USA  
Telephone (Pacific time): (650) 322-6300  
FAX: (650) 322-6398  
08/08/2020  
Order #36834

Billing & Delivery Address:  
feride-celik84@hotmail.com  
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534 Curie Dr  
San Jose, California 95123  
United States  
+18583373791

Order Reference: ESQWVAUKC  
Order Date: 08/08/2020  
Payment Method: Credit Card \$103.29  
Carrier: Fedex express saver

Product / Reference	Unit Price (Tax Excl.)	Discount	Qty	Total (Tax Excl.)
Group Embedded Figures Test: A measure of cognitive style GEFT Booklet Pack (25 booklets) - Translation : Turkish	\$62.50	--	1	\$62.50
Product Total (Tax Excl.)				\$62.50
Product Total (Tax Incl.)				\$67.97
Shipping Cost				\$35.32
Total Tax				\$5.47
Total				\$103.29

Tax Detail	Tax Rate	Total Tax Excl.	Total Tax
Products	8.750 %	\$62.50	\$5.47

**Group Embedded Figures  
Test  
Instrument and Scoring Guide**

Developed by

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## Appendix II

### Basic Process and Example Scenario of Experimental Applications

Completion of each experiment during the implementation process of the study covers a two-week period. In the first week, a problem scenario is presented by the instructor regarding the concept to be discussed, and students are asked to form their hypotheses regarding the solution of the problem in the scenario, and to design an experiment to test one of these hypotheses. In this context, one of the scenarios presented to the students during the implementation process is shown below. [In the preparation of this scenario, TUBITAK's (Türkiye Bilimsel ve Teknolojik Araştırma Kurumu-The Scientific and Technological Research Council of Turkey) Science Youth page (<https://bilimgenc.tubitak.gov.tr/makale/kartezyen-dalgicini-tasarla>) was used.

### Cartesian Diver's Movement

"When a cartesian diver is placed in a water-filled bottle in the figure below, it is seen that the diver floats, and if the bottle is squeezed from both sides, the diver sinks. You are expected to identify hypotheses that may reveal the reasons for this situation; test these hypotheses and explain the cause of the event."



After this scenario was presented during the implementation process, a discussion environment was created and the possible reasons for the situation were discussed with the students. At this stage, no teacher guidance was made regarding the reasons for the event, the students' opinions about the event were taken, and the lesson was concluded by creating a curiosity about the event. This stage covers a period of approximately 15-20 minutes. 3 days after this stage, the students sent their pre-experiment reports containing their

possible hypotheses (at least 3 hypotheses) regarding the problem situation to the instructor in charge of the course via the Microsoft Teams program. The instructor examined and evaluated the pre-experiment reports in terms of the suitability of the hypotheses (in terms of the structural features of the hypothesis) and designing an experiment in accordance with the determined hypotheses. Then, she gave the necessary feedback and corrections to the students 1 day after the same program.

Below is the pre-experiment report of the student with the code Ö1/FID.

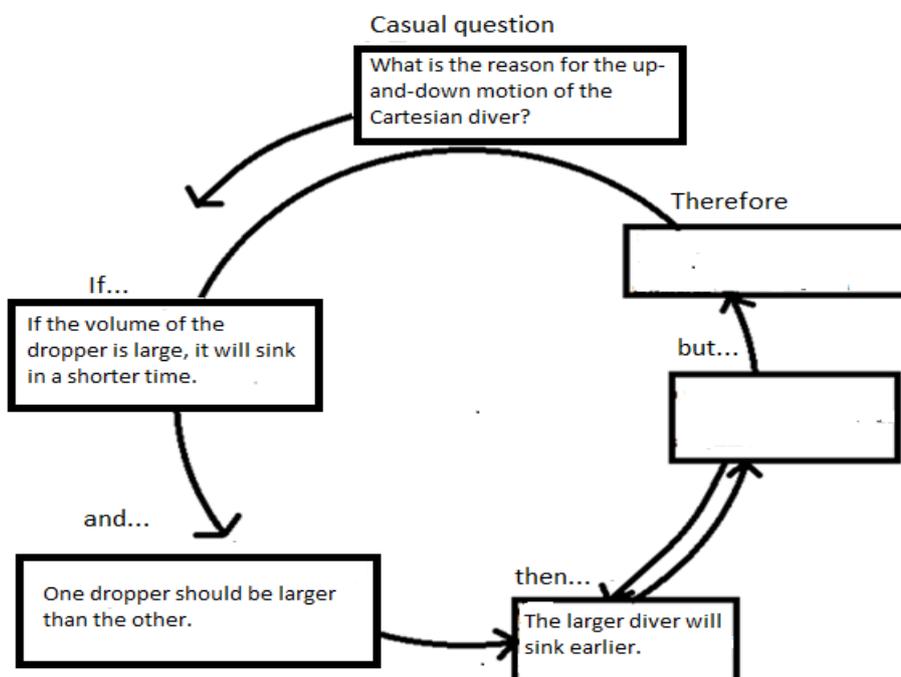
**Pre-Experiment Report of Student with Ö1/FID Code:**

(1) Hypotheses

a) My hypothesis/hypotheses for this experiment are:

- When we put a liquid with less density instead of water in the bottle, the diver will sink faster.
- When salt is put into the water, its density increases and the diver sinks more difficult.
- If the volume inside the dropper is large, the diver's sinking time will decrease.

(2) The hypothetico-deductive reasoning circle I used during the experiment



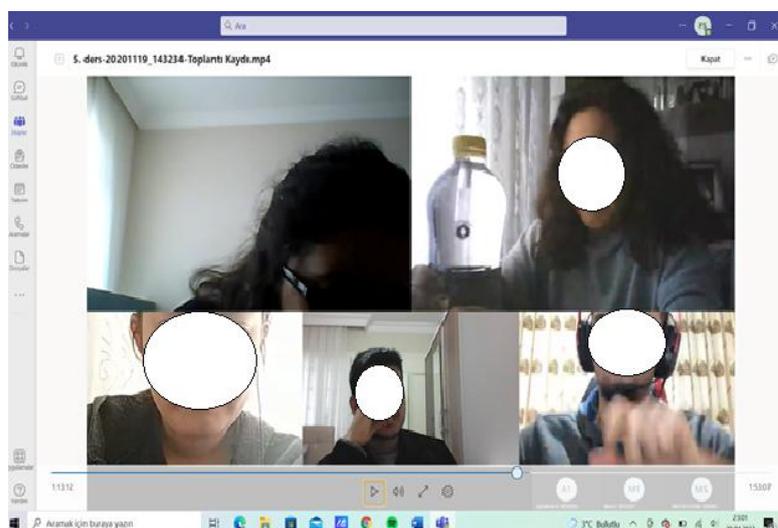
(3) The concepts covered in this experiment are:

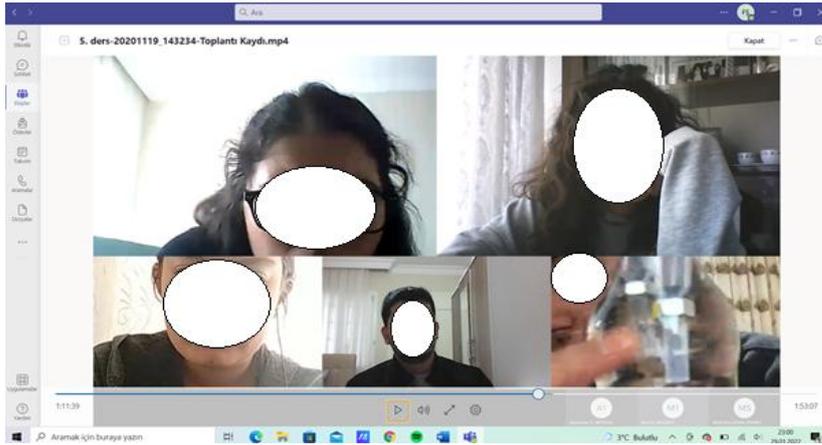
- Pressure
- Density
- Buoyancy force
- Force
- Sinking
- Swimming

In the second week of the guided inquiry learning approach-based laboratory practices in which the hypothetico-deductive reasoning cycle is used, the experiments designed to test the hypothesis were applied by the students. In this process, the students were expected to explain the judgment they reached by comparing the predicted results before the experiment with the actual experimental results (they were asked to construct this explanation by taking into account the steps of the hypothetico-deductive reasoning cycle). After this stage, the lecture was concluded by introducing the concept discussed by the lecturer (also one of the authors of the study) and associating it with daily life.

The students sent their post-experiment reports about the experiment 3 days later via the Microsoft Teams program. In this process, the students were given the necessary feedback and corrections again. In the post-experiment reports, students were asked to design a scenario related to the basic concept discussed in the experiment, and it was tried to deepen the connection of the concept with daily life and its application. In other words, students were asked to prepare a thought experiment at this stage.

Below are the images of the students regarding the experiment and the post-experiment report of the student with the code Ö1/FID. (Ethical permission regarding the use of sound and video within the scope of the study and voluntary consent from the students were obtained. However, the clarity of the students' images was somewhat reduced.)





**Post-Experiment Report of Student with Ö1/FID Code:**

(1)

(i) Here are the procedures I followed during this experiment:

- First, I tried to figure out how the diver would sink.
- Later, I learned the mechanics of the diver's sinking.
- I thought about how to change the diver's sinking time.
- I thought that when I changed the size of the diver, the sinking time would also change.
- I made two divers in the experiment and calculated the sinking times.

(ii) My experimental setup is as follows.



(2) Observations and Findings

(i) The independent variable(s) in this experiment are:

Divers size

(ii) Dependent variable(s) in this experiment:

Sinking time

(iii) Variable(s) controlled in this experiment:

Applied force

(iv) Here are the situations I observed in this experiment:

The big diver sank later than the small diver.

(v) Here are the information/data I recorded throughout the experiment:

I found it convenient to show the data I recorded with a table.

**Table 1: Sinking Time by Diver Size**

<b>Divers size</b>	<b>Force</b>	<b>Sinking time</b>
4 cm	Equal	2 seconds
8 cm	Equal	5 seconds

(3) Evidence

Here is my evidence supporting/rejecting my hypothesis:

- That made my hypothesis rejected was that the great diver sank later.
- The logic was correct, but the opposite happened, so I rejected my hypothesis.

(4) Reflection

(i) Here are the conclusion(s) I drew from this experiment:

The big diver sinks later than the small diver.

In the experiment, I learned that the sinking time of the object (cartesian diver) depends on the applied force.

The water entering the dropper compresses the air and the density increases.

The floating or sinking of the object (cartesian diver) in the liquid is related to the density.

(ii) My thoughts at the beginning and end of this experiment were the same/different. This may be due to:

My thinking at the beginning of this experiment was different. Because I thought the big diver would sink faster. But when I did the experiment, the little diver went down faster.

(iii) Here's what this experiment has given me:

In order for the diver, which is larger in volume, to sink to the bottom of the water, more water must enter it. Therefore, it sinks later.

(iv) I can use/apply the result of this experiment in the following events in daily life:

I learned the effect of density on the sinking and floating state of an object.  
What I learned;

Diving to the bottom of the sea and

I can use it to explain the physiology of fish swimming in water.

(v) Here are the experimental mistakes that I have made / may have made in this experiment:

I couldn't get the result I wanted when I first did it while adjusting the size of the divers. I could not observe the difference. But then when I increased the size of the diver, the experiment was correct.

(vi) The challenges I faced in this experiment are:

I had difficulties in creating different sizes of Cartesian divers.

(vii) To overcome these difficulties, I did the following:

Since we were in the classroom during the experiment, I adjusted the diver dimensions with the help of our teacher and completed the experiment without any errors.

(5) Daily life examples and thought experiment

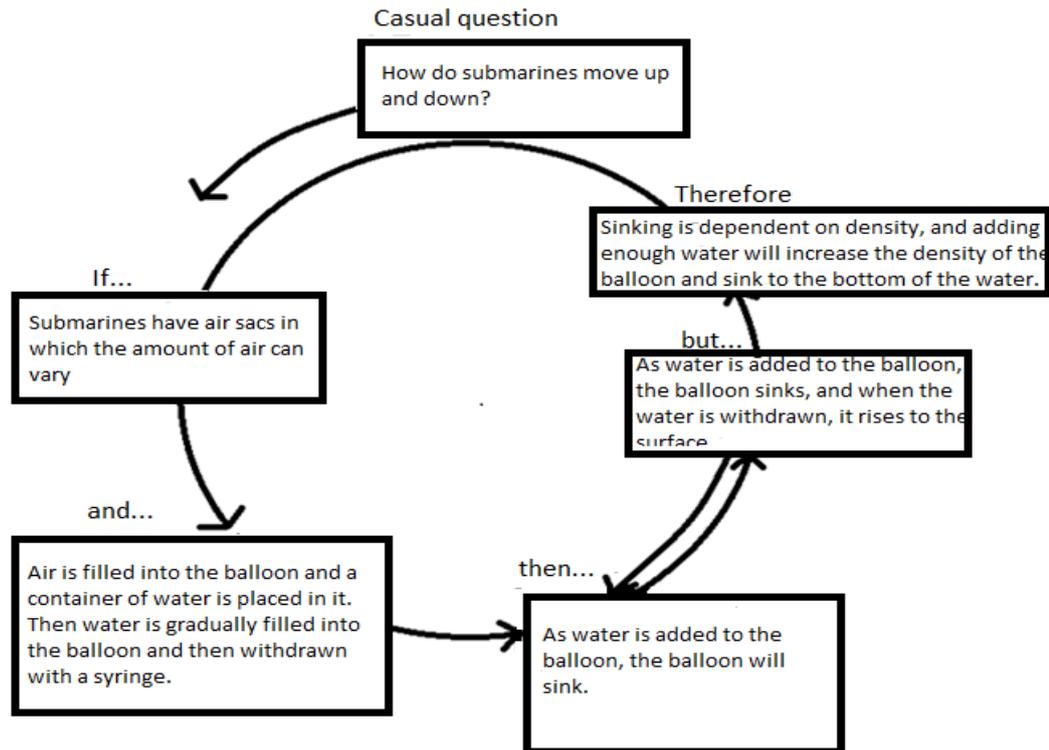
At this stage, you are expected to design a thought experiment that includes your hypotheses about this concept by giving daily life examples of the information you have learned as a result of the experiment.

Research question: What allows submarines to be on the surface whenever they want and at the bottom when they want?

**Hypotheses:**

Submarines sink depending on the load.

Submarines sink into the water with a special mechanism.



At the end of the lesson, a scenario presentation for the next week's experiment was made and a similar process was run for all experiments except the example.

In this experiment report presented, the student's (S1/FID coded student) writing is presented here without any changes. During the application process, students were given feedback on the parts that made mistakes or were missing, especially in the pre-experiment reports. The same feedback process was used for the post-experimental reports. For example, in the 'b' part of the 'reflection' part of this experiment report, the difference between the thoughts at the beginning and the end of the experiment was explained by the student, but it was understood that no explanation was given about the reason. Therefore, feedback was given to the student regarding these parts by the instructor of the course. Similarly, in the "daily life examples and thought experiment" section in the 5th chapter, the student prepared the thought experiment but did not present daily life examples. In this regard, the instructor of the course gave feedback to the student.

As a result, the example presented here; it was used to provide information on how the guided inquiry learning approach-based laboratory applications, in which the hypothetico-deductive reasoning cycle is used, is carried out. The main purpose is to show the order of the process steps and the way they are implemented, to exemplify at what stage and how the cycle is used, thus making the process more understandable for the reader.