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An Investigation of the Effectiveness of 5th Grade Guided Inquiry-Based Activities in Terms of Skills and Perception

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We investigated the effects of guided inquiry-based laboratory activities on the perceptions of the research skills and inquiry learning skills in science of 5th grade students. The sample of this study consisted of 38 students enrolled in a public secondary school located in the northwest part of Türkiye. This study is based on the non-equivalent control group pretest/posttest model of the quasi-experimental design. Data collection tools were a Research Skills Test, Scale of Inquiry Learning Skills Perception in Science, and a semi-structured interview form. We analyzed the quantitative data with the Mann-Whitney U test from nonparametric statistical methods and the qualitative data by using content analysis. We established a significant difference between the two groups' research skills and perception about the inquiry-based learning skills of science, in favor of the experimental group.

Nous avons étudié les effets des activités de laboratoire guidées basées sur l'enquête sur les perceptions des compétences de recherche et des compétences d'apprentissage par l'enquête en sciences des élèves de 5e année. Pour cette étude, l'échantillon était composé de 38 élèves inscrits dans une école secondaire publique située dans le nord-ouest de la Turquie. Cette étude est basée sur le modèle prétest/post-test de groupe de contrôle non-équivalent de la conception quasi-expérimentale. Les outils de collecte des données étaient un test de compétences de recherche, une échelle de perception des compétences d'apprentissage de l'enquête en sciences et un formulaire d'entrevue semi-structurée. Nous avons analysé les données quantitatives à l'aide du test U de Mann-Whitney à partir de méthodes statistiques non-paramétriques et les données qualitatives à l'aide de l'analyse de contenu. Nous avons établi une différence significative entre les compétences de recherche des deux groupes et leur perception des compétences d'apprentissage des sciences basées sur l'enquête, en faveur du groupe expérimental.

The inquiry-based approach in science education aimed at developing scientific knowledge and skills has become an important focus point in international science curricula (e.g., Australian Curriculum Assessment and Reporting Authority, 2018; British Columbia Ministry of Education, 2018; Heinz et al., 2017; Turkish Ministry of National Education [MoNE], 2018). In this context, science education researchers have focused on studies related to supporting students' inquiry skills (e.g., Kapici et al., 2022; Kruit et al., 2018; Ortiz & Aliazas, 2021).

The existing debate about the effectiveness of inquiry-based instruction in terms of student outcomes in science education has drawn attention in recent years in the research literature (see Aditomo & Klieme, 2020; Cairns, 2019). Vorholzer and von Aufschnaiter (2019) stated that the effectiveness of inquiry-based instruction "depends on how it is implemented and which particular goal it attempts to achieve." (p. 1563). Effective science education is contingent upon multiple factors, including good curricula. Hence, the use of appropriate teaching approaches or methods in science teaching curricula are of great importance. Science courses should include learning environments in which the activities of discovering can be performed effectively. In addition, the textbooks prepared according to the current curricula are also important tools in achieving the educational goals. Although many studies support that students can gain important outcomes with inquiry-based instruction (e.g. Cheng et al., 2014; Concannon et al., 2020; Heindl, 2019; Lazonder & Harmsen 2016; Murphy et al., 2021), conducting inquiry practices is limited to classroom activities depending on resources, such as time, space, and equipment (Eliyahu et al., 2021).

In the literature, the effects of inquiry-based instruction vs. teacher-centered instruction have been studied extensively, However, it can be stated that the effects of different types of inquiry have still not received as much attention. Researchers have argued that an instruction based on guided-inquiry, which allows students to explore concepts, ideas, and phenomena through guided-inquiry before the teacher explains, has positive effects on students' performance in science and aspects of inquiry, such as conducting scientific investigations and drawing conclusions from data (Aditomo & Klieme, 2020; Marshall et al., 2017). For this reason, it can be assumed that there is a need for more data, especially to be obtained with experimental research models, on the effects of guided inquiry-based teaching. To this end, it is of great importance to develop original activities based on the inquiry approach and to evaluate their effectiveness in terms of various variables for both students and teachers in achieving the targeted acquisitions in science courses.

Theoretical Framework

Inquiry-based Science Education (IBSE)

The theoretical paradigm of inquiry-based science education (IBSE) is grounded in the constructivist approach, which is a huge umbrella term subsuming a wide range of methods for teaching and learning (see Constantinou et al, 2018; Prince & Felder, 2006).

We can see the basic and important information about IBSE for science teaching and learning in the published documents. Although there is not a single, clear definition for IBSE, we see common features in the reports. For example, students encounter scientific questions or problems; plan and conduct investigations; collect data and evidence; analyze and evaluate data; draw conclusions and develop explanations; evaluate their explanations; communicate and verify their explanations, etc. (National Research Council [NRC], 2000; 2012; 2013). IBSE includes inquiry-based science teaching and learning. Inquiry-based instruction is accepted as an important teaching strategy for science education to achieve the intended goals of scientific practices, such as inquiry-based learning skills, by engaging students in inquiry activities (e.g. Crawford, 2014; Vorholzer & von Aufschnaiter, 2019).

Inquiry Levels

Researchers (e.g. Banchi & Bell, 2008; Blanchard et al., 2010; Buck et al., 2008; Hackling, 2005) typically divide scientific practices of inquiry into four levels depending on the types of activity students engage in and the degree of guidance provided by teachers:

1. *Verification or Confirmatory Inquiry*: The problem or research question to be investigated, equipment, procedure to be followed, and conclusion are all given to the students by the teacher. This type is the lowest level of inquiry.
2. *Structured Inquiry*: The problem situation or research question and the procedure to be followed are given by the teacher, while the students follow this path to reach conclusions and create their own explanations based on the data and evidence they have collected.
3. *Guided Inquiry*: Teacher gives the problem situation or research question (equipment can also be provided) to be investigated to the students. Students design/plan and carry out research to solve this problem/question, obtain and analysis data, draw conclusions, and create their own explanations. The teacher's direction is reduced.
4. *Open Inquiry*: The students are required to determine everything for themselves. They identify a problem to be investigated, design and plan research to solve this problem, obtain and analyze data, draw conclusions, and create their own explanations. This type is the highest level of inquiry and allows them to act like scientists.

Inquiry-based Laboratory Activities for Engaging Students in Scientific Practices

An inquiry-based instruction offers opportunities such as students creating their own scientific questions with effective thinking activities, searching and using evidence in answering questions, constructing evidence-based explanations, and sharing their explanations by communicating with their friends (Bybee, 2006; NRC, 2000). However, achieving these goals depends on the nature of the learning environments created in science courses.

One of the learning environments of science courses is the laboratory, which has a crucial role in understanding science (Hofstein & Kind, 2012; Hofstein et al, 2004) and the potential to gain many skills for students. It is important to use appropriate teaching approaches for an effective laboratory application. In inquiry-based laboratories, students have opportunities to solve a problem through experimenting and to establish a connection between observable events and scientific ideas (Millar et al., 2002).

Inquiry levels can be also defined as inquiry-based laboratory levels (see Chatterjee et al., 2009). In science education, research or investigation skills are also related to experimental skills. Kalthoff et al. (2018) described experimental skills as the skills required to plan and perform experiments and evaluate experimental data.

Literature Review

In recent years, there has been an increasing interest in school science departments in the inquiry practice. Considering the studies on the inquiry approach at secondary school level, it is seen that there are studies on the development of students' inquiry skills/inquiry learning skills perceptions (Hairida, 2016; Varlı & Uluçınar Sağır, 2019) and research skills (Bunterm et al., 2014; Chu, 2008; Çıtak, 2016).

When reviewing the literature on the effectiveness of guided-inquiry on primary and secondary school students, fewer experimental studies were found than general inquiry-based instruction. A number of researchers have compared the effects of different types of inquiry. In their study comparing the effects of guided vs. structured laboratory activities, for example, Bunterm et al. (2014) applied instructional intervention incorporated laboratory activities into the 5E learning model for the 7^{th} and 10^{th} grade students. They revealed that guided-inquiry groups, both 7^{th} and 10^{th} grade students, acquired greater improvement in both science content knowledge and science process skills than the structured-inquiry groups of both 7^{th} and 10^{th} grade students. Varlı and Uluçınar Sağır (2019) studied the unit of spread of light and sound with 5^{th} grade students. They determined that guided inquiry-based instruction had a significant effect on students' perceptions of inquiry learning skills and academic achievement, when compared with the control group studying with the textbook. In another study by Aydın (2020), the 4^{th} grade students performed guided-inquiry activities embedded in the 5E learning model. They studied in the regular classroom environment, in contrast to Bunterm et al.'s study. Similarly, Aydın found that guided inquiry-based activities had positive effects on the students' group working, learning concepts, and interest to science.

Comparing the results of the aforementioned studies, it can be seen that guided-inquiry instruction has positive effects on students' intended learning outcomes regardless of whether the learning environment is a classroom or a laboratory. Alternatively, in their long-term study, Szalay et al. (2020) concluded that through two-year chemistry lessons, there was no significant change in 12- and 13-year-old students' experimental design skills (studied via guided-inquiry activity) when compared to the control group (carried out step-by-step experiments only) or the second experimental group (carried out the step-by-step experiments and did theoretical experimental design tasks on paper).

If we move onto laboratory skills, Mistry and Gorman (2020) claimed that it's important to know what laboratory skills students possess before the course starts in order to be able to design a laboratory course. They studied what laboratory skills students have at their university education stage. In a striking result, they stated that the university students consider that they are deficient in the knowledge, experience, and confidence to perform designing experiments and problem-solving competencies, whereas they have the knowledge, experience, and confidence for performing lower-order competencies, such as practical techniques. This is probably because the participants of Mistry and Gorman's study might not have engaged in inquiry activities as frequently as desired in elementary to high schools' science courses. Crujeiras-Pérez and Jiménez-Aleixandre (2017) scrutinized the process of high school students' planning and carrying out investigations during two consecutive academic years. They established that the students could not perform some aspect of inquiry, such as to decide measurement criteria and understand the importance of repeating measurements, despite progressing in planning. These findings support the results of Mistry and Gorman's study (2020). Stender et al. (2018) studied 8^{th} grade students to investigate the influence of scientific reasoning skills on their conceptual learning through variable-based experiments based on guided-inquiry of electromagnetic force and the brightness of light bulbs. They reported that the students' scientific reasoning skills had a direct effect on content knowledge learning gains.

Taking into account the ongoing debate on the effectiveness of the inquiry approach, Cairns (2019) sought the relations of inquiry-based instructional practices and science achievement in an inquiry-based learning environment in 69 countries through a correlational study based on data from the Program for International Student Assessment (PISA) 2015. Cairns revealed that science achievement negatively associated with items of students explaining their own ideas and doing experiments. In addition to the negative relationship between science achievement and doing experiments, a more detailed result was that the science achievement scores of students who experimented in the lab "in some lessons" were higher than those who were doing experiments in the classroom "in all lessons" (Cairns, 2019).

As mentioned above, different results can be seen of the effectiveness of inquiry instruction and laboratory activities on intended learning outcomes. Therefore, we need more particularly experimental studies in order to obtain evidence about the effects of guided inquiry-based laboratory activities.

Context of the Study

According to the meta-analysis studies carried out by Alfieri et al. (2011), and Lazonder and Harmsen (2016), adequate and effective guidance to students in the inquiry learning environment has a great impact on learning gains and performance success. In this context, we focused on guided inquiry laboratory activities, and revealed the effect of laboratory activities in terms of students' skills and perceptions.

In Türkiye, an inquiry-based approach was adopted in the science curricula for secondary schools (5^{th}, 6^{th}, 7^{th}, and 8^{th} grades) prepared by the Ministry of National Education [MoNE] in 2013 and updated in 2018 (MoNE, 2013; 2018). Bayır and Kahveci (2021) examined the level of representation of the textbooks prepared according to the 2018 secondary school science curriculum in terms of the levels of inquiry activities. According to the results of Bayır and Kahveci, the general structured-inquiry level activities in the books at all grade levels are very high compared to the guided- and open-inquiry level activities. Since the current study was conducted with 5^{th} grade students in the unit of Matter and Change, and considering the results of Bayır and Kahveci's research, especially regarding this unit in the 5^{th} grade textbooks, 10 out of 11 activities were at a structured-inquiry level and only 1 was at the guided-inquiry level. This creates a greater need to develop inquiry activities that can be applied in learning environments and to evaluate them from various perspectives.

In this study, guided-inquiry activities were developed at the 5^{th} grade level of a secondary school and their effects in terms of skills and perception were evaluated. It is thought that in this context, the study will contribute to the science education literature, both in terms of how the materials or activities in the textbooks can be redesigned in line with the targeted acquisitions and in terms of the findings obtained within the scope of the research.

Based on their literature review, Schwichow et al. (2022) pointed out that elementary school students are unsuccessful in planning and implementing variable-based experiments, whereas they can correctly identify and interpret the results of controlled experiments to test given hypotheses. The researchers collected data via paper and pencil tests in order to find out the German elementary students' (from 2 to 4 grades) skills in the planning errors of controlled experiments. In this regard, we believe in the importance of developing students' experimental skills in their early years. Although inquiry-based learning is generally an effective approach in secondary school and university level education, it is necessary to explore secondary school learning environments where the guided-inquiry learning strategy is used to teach science. Students should be engaged actively in scientific practices rather than merely learning about science content (NRC, 2012). Taking into account this proposal, we consider that guided-inquiry based laboratory tasks constitute an appropriate way to this end. Additionally, guided-inquiry could be a good chance to face the difficulties of more complex open-inquiry laboratory tasks.

Aim and Research Questions

In this study, we aimed to examine the effects of guided inquiry-based laboratory activities on 5^{th} grade students' research skills and inquiry learning skills perception in science. To this end, the following research questions and hypotheses were formulated:

RQ 1: Is there statistically a significant difference between the Research Skills Test posttest scores of the students in the experimental and control groups?

RQ 2: Is there statistically a significant difference between the Scale of Inquiry Learning Skills Perception in Science postscores of the experimental group and control group students?

RQ 3: What are the students' views on the implementations?

H01: There is no statistically significant difference between the posttest scores of the Research Skills Test of the experimental group and control group.

H02: There is no statistically significant difference between the posttest scores of the Scale of Inquiry Learning Skills Perception in Science of the experimental group and control group.

Method

Model of the Research

We designed this study based on the explanatory sequential pattern from mixed research methods (Creswell & Plano Clark, 2011). In the explanatory sequential design, firstly, quantitative data is collected and analysed. After this analysis, that is, following the results; qualitative data are collected and analysed. The data obtained from the quantitative measurement tool(s) are explained and interpreted through the data obtained from the qualitative measurement tool(s). In this way, the two data sets are combined by blending them with each other. We used the non-equivalent control group pretest/posttest model of the quasi-experimental design (Fraenkel et al., 2011) to collect the quantitative data of the study. The research model is summarized in Table 1.

Table 1

Model of the Research

Group	Control	Experiment
Pretest	RST; SILSP	
Experimental process	Laboratory activities based on confirmative and/or structured inquiry	Laboratory activities based on guided inquiry
Posttest	RST; SILSP	
	Analysis of quantitative data	
	Collection of qualitative data (semi-structured interview)	
	Analysis of qualitative data	
	Combining quantitative and qualitative data	

Sampling

We conducted this study with thirty-eight 5^{th} grade students enrolled in a state school in the 2019-2020 academic year. The school that constitutes the sample of the study is located in the city center of a medium-sized province in the northwest of Türkiye.

Participants are selected without random assignment to experimental and control groups because, in our country, classes are formed by the related principals in the schools. There are 6 classes including 5^{th} grade students in the secondary school where the second author of this study also works as the school's science teacher. We selected the sample of the study through convenience sampling since the difference of the teachers of these six 5^{th} grades could damage the experimental design. Convenience sampling is when researchers select a sample that is close and easy to access (Büyüköztürk et al., 2012). Accessibility of the chosen sample provides speed and practicality in terms of the progress of the research. For this reason, one of the two classes forming the sample of the study, in which the second author has taught the science course, was determined with random assignment as the experimental group and control group. The second author implemented all of the treatments over the study and collected data, and prevented the existence of any internally threatening factors by making special efforts to be impartial in the groups. The experimental group consisted of 21 students (11 girls and 10 boys) and the control group consisted of 17 students (6 girls and 11 boys). The students had not been involved in any inquiry-based laboratory study before.

We collected the qualitative data of the study through a semi-structured interview. In the selection of students who would participate in the semi-structured interviews, we used the posttest scores obtained by the students from the quantitative data collection tools. We took the average of the posttest scores of the students in the experimental group and according to these average scores, we determined a total of 12 students (6 in the experimental group and 6 in the control group) with two students each with the highest, middle, and lowest average scores.

Data Collection Tools

In the present study, we used the Research Skills Test (RST) and the Scale of Inquiry Learning Skills Perception (SILSP) in Science as the quantitative data collection tools and applied them to the students in the experimental and control groups before and after the instructional procedures. Also, we utilized a semi-structured interview form as the qualitative data collection tool and interviewed the students after instructional intervention.

The Research Skills Test (RST) was developed by Alkan Dilbaz et al. (2012). The test consists of 20 multiple-choice items of curiosity, defining the problem and determining the variables, hypothesizing, data collection, data analysis and evaluation, presenting results, and knowledge about the research process. The reliability coefficient of the test was calculated as KR-20 = 0.76 by Alkan Dilbaz and others. In this study, we calculated the KR-20 coefficient as 0.63 for the posttest. In general, if the reliability coefficient of a measurement tool is above 0.70, the measurement tool is considered reliable. However, since the number of samples in this study is quite low compared to that of developing a measurement tool, we obtained a value close to 0.70. One of the items in the RST test is shown below as an example (this item was translated into English by the authors for this paper, not by Alkan Dilbaz et al.):

A study is being conducted to determine the effectiveness of the newly produced stain remover. For this, the fabric is cut into 6 pieces of the same size. Each piece is smeared with a different stain. The same amount of stain remover is poured on the stains and the stains are removed. It is then recorded how long it took for each stain to come off. How should the effectiveness of the stain remover be determined in this research?

a. According to the type of fabric
b. According to the duration of removal of the spots
c. According to the quality of the stain remover
d. According to the amount of stain remover used (p. 330)

The Scale of Inquiry Learning Skills Perception (SILSP) in Science was developed by Balım and Taşkoyan (2007). The scale is five-point Likert-type from *totally agree* to *never agree*. We applied the scale to the experimental and control groups before and after the instructional process. The Cronbach Alpha reliability coefficient of the scale was calculated as 0.84 by Balım and Taşkoyan, and in this study, we calculated it as 0.87 for the posttest. One of the items in the SILSP in Science scale is given here as an example (this item was translated into English by the Authors for this paper, not by Balım and Taşkoyan): *I discuss with my friends to decide the accuracy of my experimental results*.

The Semi-Structured Interview Form was prepared by the researchers and used to provide supportive data in the interpretation of the findings obtained from the quantitative data collection tools. The Semi-Structured Interview Form consists of nine open-ended questions. We prepared the form based on the two quantitative data collection tools used in the study. Following preparation of the form, we received the opinion of two science educators and established the final version of the form, based on the responses we received. The second author performed the interview in an environment where the student could sit comfortably, and was sufficiently illuminated and quiet. The students were interviewed individually. One of the interview questions is as follows: *What kind of work did you do to make sure the accuracy of obtained knowledge with your experiments?*

Instructional Process

We divided the participants into two groups, experimental and control. We conducted guided inquiry-based laboratory activities with the experimental group but traditional teacher-centered confirmatory and/or structured laboratory activities in the control group for the 5th grade Matter and Change unit topics. For the application, we first examined the current science curriculum (MoNE, 2018) and listed the following acquisitions regarding the relevant unit:

1.1. Makes inferences based on the data obtained from her/his experiments that show that substances can change their state with the effect of heat.

2.1. Determines the melting, freezing and boiling points of pure substances as a result of her/his experiments.

3.1. Explains the basic differences between heat and temperature.

3.2. Interprets the results by doing experiments on heat exchange as a result of mixing liquids with different temperatures.

4.1. Discusses the results of the experiments by conducting experiments on the expansion and contraction of substances under the influence of heat.

4.2. Relates examples from daily life with expansion and contraction events.

After the pretest administration in both groups, we started the instructional activity applications.

For the instructional implementation, we first divided the students in both groups into cooperative groups consisting of three or four people by drawing lots, and we assigned responsibilities such as the secretary, material supervisor, and spokesperson, etc. according to the number of members in the group.

All experiments within the scope of this current study were carried out with these same heterogeneous groups. We prepared worksheets for students in both the experimental and control groups, taking care to give enough space to enable them to take notes effectively during the activities. After the activity applications, we administered the quantitative measurement tools as a posttest. After the analysis of the quantitative data, the second author conducted semi-structured interviews with six students selected according to their scores. In both groups, the research was completed in 23 lesson hours, including the application of data collection tools, and six activities were carried out. The activities were carried out within the scope of the study, and the targeted acquisitions and concepts are presented in Table 2. As for the names of the activities, we gave the names of the concepts that were aimed to be learned for the control group, while giving names that would attract attention to the activities for the experimental group.

Implementations of The Experimental Group

In the light of the relevant acquisitions, we determined which subjects we could develop as activities, and we searched for experiments on these subjects in the literature, online, and in books. Next, considering the students' grade level and educational background, we developed guided inquiry-based activities. We adapted the activity phases from the phases of Hofstein et al.s' study (2004). According to Hofstein et al., inquiry-based laboratory activities start with a small experiment conducted to draw attention and a preliminary inquiring step involving observations of the experiments. The next stage is inquiring which questions are asked to be investigated, and

Table 2

Activities Carried out Within the Scope of the Study, Targeted Acquisitions, and Concepts

Activity name		Acquisition number(s)	Concepts
Experimental group	Control group		
Mother's Day Celebration	Freezing, Melting	1.1	Freezing, Melting
I have a cold	Boiling, Evaporation, Condensation		Boiling, Evaporation, Condensation
Where is the ice?	Defrosting, Sublimation		Defrosting, Sublimation
Egg machine	Freezing and Melting Point, Boiling Point	2.1	Freezing and Melting Point, Boiling Point
If the electricity goes out!	Heat, Temperature, Heat Exchange	3.1 3.2	Heat, Temperature, Heat Exchange
The mystery of money	Expansion, Contraction	4.1 4.2	Expansion, Contraction

a hypothesis is created based on these questions. Then, an experiment is recommended to test the hypothesis and it is performed. Observations are made, data are collected, and it is stated whether the hypotheses are supported or not, based on the obtained data. Accordingly, we started the activities with a scenario in order to provide preliminary inquiries for the students, and we presented the problem of the research within this scenario. We aimed to make students realize the problem by reading this scenario. In order to solve the given problem situation, we asked the students what they should investigate and determine in their hypotheses. We then told the students to design an experiment to test their hypotheses. After the students designed their experiments, they performed their experiments and collected data. Based on the data collected in the final stage, we guided the students to interpret the results and reach the targeted concepts. We prepared the activity worksheets in such a way that they included the stages we mentioned above. In the first activities, we presented blank tables and graphs to guide students in drawing tables and graphs. We presented the application plans and activity worksheets for the developed activities to four field experts for their opinions; two of the experts are chemistry educators and two are science educators. We finalized the activities in the light of their feedback.

First, due to the lack of inquiry-based laboratory experience of the experimental group students, we conducted an orientation activity. We received expert opinion for the validity of the guided inquiry-based orientation activity called Pınarlı Village's Roads, which we developed to examine the effect of friction force on movement in various environments. With this activity, we aimed for students to gain experience about inquiry-based research and its stages. After the orientation, we carried out the activities developed for this study. The activity worksheet for Mother's Day Celebration, which is the first of the activities implemented in the study, is presented in Appendix A. During the activity, the teacher followed the activity implementation plan, guided the students with explanations where necessary according to the nature of the activity, held in-class discussions, and asked questions that triggered the inquiry. Each activity was completed in three lesson hours.

Implementations of The Control Group

We performed the implementations in the control group in two stages. First, we taught the relevant subject based on the traditional teacher-centered approach. We used techniques such as question and answer, brainstorming, and the narrative of connected concepts during the teaching of the subject. Following the subject teaching, we conducted a confirmatory and/or structured laboratory activity with the students on the relevant subject. For this purpose, we used the worksheets that we had prepared, including information such as the experiment’s name, the purpose of the experiment, tools, and the method of the experiment, step by step. We asked the students to perform the experiment by following the instructions. After the relevant experiment was completed, we switched to a new topic and followed the experiment for the relevant subject following the subject taught. A worksheet from the applications in the control group is presented in Appendix B.

Analysis of Data

In the present study, we applied non-parametric statistical analysis techniques to compare the data obtained from the quantitative data collection tools RST test and SILSP scale, since both groups did not have a sufficient sample size (30 and above) (Büyüköztürk, et al., 2012; Pallant,

2015) in order to meet the parametric assumptions. We employed the Mann-Whitney U test to compare the pretest and posttest scores of the experimental and control groups, which are two independent samples (Büyüköztürk, et al., 2012).

We used content analysis in the analysis of the qualitative data of the study. Content analysis consists of four stages: coding the data, creating the themes, organizing the codes and themes, and defining and interpreting the findings (Yıldırım & Şimşek, 2013). The second author recorded the interviews and then listed the student statements anonymously on the basis of the questions. Two coders worked separately to determine the codes and themes for the analysis, and then the findings were brought together and the themes and codes were finalized in line with the joint decisions taken. After this process, the data were organized as codes and themes, the frequencies were calculated, and the data were interpreted in the final stage.

Results

Effect of Guided Inquiry-Based Laboratory Activities on Research Skills of 5th Grade Students

Firstly, we established that there was no significant difference between the Mann-Whitney U test and the RST pretest scores of the experimental and control groups (U = 119.500, p>0.05). Then, we analyzed whether there was a statistically significant difference between the RST posttest mean scores of the groups with the Mann-Whitney U test. The Mann-Whitney U test results of the RST pre- and posttest comparisons of the experimental and control groups are shown in Table 3.

According to the Mann-Whitney U test analysis results, we determined that there was a significant difference between the posttest scores of the groups in favour of the experimental group (U = 108.000, p<0.05). Based on this result, the hypothesis H_{01} with related RQ1 was rejected.

Effect of Guided Inquiry-Based Laboratory Activities on 5th Grade Students' Perception of Inquiry Learning Skills in Science

Initially, we investigated the equivalence of the groups in terms of their perception of inquiry learning skills of science using the Mann-Whitney U test, and we found that there was no significant difference between the pretest scores of the groups (U = 139.500, p>0.05). Then, we examined whether there was a statistically significant difference between the posttest scores of the groups. The Mann-Whitney U test results comparing the pre- and posttest mean scores of the groups on the SILSP in Science scale are given in Table 4.

Table 3

RST pre- and posttest Mann-Whitney U Test Results

Test	Group	N	Mean rank	Sum of ranks	U	p
Pretest	Experiment	21	22.31	468.50	119.500	0.081
	Control	17	16.03	272.50		
Posttest	Experiment	21	22.86	480.00	108.000	0.037*
	Control	17	15.35	261.00		

*p<0.05

Table 4

SILSP in Science pre- and posttest Mann-Whitney U Test Results of the Groups

Test	Group	N	Mean Rank	Sum of Ranks	U	p
Pretest	Experiment	21	21.36	448.50	139.500	0.252
	Control	17	17.21	292.50		
Posttest	Experiment	21	23.64	496.50	91.500	0.011*
	Control	17	14.38	244.50		

*p<0.05

According to Table 4, there is a statistically significant difference in favor of the experimental group between the posttest (U = 91.500, $p<0.05$) scores of the groups. Based on this result, the hypothesis H_{02} with related RQ2 was rejected.

Students' Views on the Implementations

In order to support the quantitative data, we evaluated the data obtained from semi-structured interviews with twelve students in the experimental (6) and control (6) groups with content analysis. The results obtained are presented in Table 5.

According to the results of content analysis, all students interviewed considered the applications contributed to their learning. Students in both the experimental and control groups stated that the applications contributed to increasing their better understanding and interests. For example, one student in the control group stated, “I became more interested in the lesson with the activities”. When the research done by the students in practice is evaluated, it is seen that all of them observe more when they go home. The highest frequency is the research source, followed by the internet and books. The students in the experimental group expressed the following views: “I made sure that it was correct by repeating the experiment I did at home.”, “I researched the subject in my books. I also did research in my class during the experiment.”, “Apart from the experiments we did, I also did research on the internet at home. I also performed the experiment that we had done in the class at home too.” A student from the control group also stated, “When I went home, I made observations at home while my mother was boiling water”.

When the parts that the students found most difficult with were examined, the control group students stated that they had the most difficulty while doing the experiment. They claimed that the reason for this was the observations could not be made correctly, or they could not record the data correctly while doing the experiment. The experimental group, on the other hand, had the most difficulty in hypothesizing and experimental design, and they asserted that they had not taken part in such an application before. A student from the experimental group said: “I have never been involved in such practice before. That's why I had difficulties in some stages such as forming hypotheses and designing experiments”. Another student stated, “I was confused while recording the data because I had difficulty deciding, and I mixed up the temperature and time values”.

Table 5

Semi-structured Interview Results of Students

Theme	Code	Control H (f)	Control M (f)	Control L (f)	Experiment H (f)	Experiment M (f)	Experiment L (f)
Whether the applications contributed or not	They contributed	2	2	2	2	2	2
Contributions made by applications	Better understanding	2	1	1	2	1	2
	Increased interest in the lesson	1	1	1	1	1	-
	Improving observation skills	-	-	-	2	-	-
Contribution to the group	I contributed	2	2	2	2	2	2
Research in group work	Observing at home	1	1	1	1	1	1
	Researching concepts	-	-	-	1	1	-
	Asking your friends	1	-	-	-	-	1
Resources used in the research	Making observation(s)	1	1	1	1	1	1
	Books	-	-	-	1	-	-
	Internet	-	-	-	1	1	1
The most difficult part in applications	Designing an experiment	-	-	-	-	1	1
	Decision-making based on results	-	1	-	-	-	1
	Drawing a table/chart	1	-	-	-	-	1
	Doing an experiment	1	1	1	-	-	-
	Hypothesizing	-	-	-	1	1	-
	Data collection/Data recording	-	-	1	1	-	-
Reason for having difficulty	Taking wrong notes	-	1	-	-	-	-
	Not enough observation	1	-	1	-	-	-
	Noise in exchanging ideas within the group	-	1	-	1	-	-
	Confusing while data recording	1	-	1	-	1	1
	Not having done such an application before	-	-	-	1	1	1
	Making a decision	-	-	-	-	-	1
The accuracy of what is read or heard	Not true	2	2	2	2	2	2
The reason why not everything read or heard is considered true	Likelihood of not being true	1	1	1	-	2	1
	Not researched enough	-	1	-	1	-	1
	Thinking like scientists	-	-	-	1	-	-
The work done to ensure the accuracy of the information obtained during the research during the applications	Checking when measuring	1	-	-	-	-	-
	Experimenting	1	1	1	1	1	1
	Asking my friend	-	-	1	-	-	-
	Consulting my teacher	-	-	1	1	-	-
	Doing research on the internet	-	-	-	1	-	-
	Reaching consensus by asking	-	-	-	-	1	-
	Repeating the experiment	-	-	-	-	-	1
Suggestions for applications	Willingness to work with friends who will be more active	1	1	-	-	-	-
	Using more material	1	-	-	1	1	1
	Individual experimentation	-	1	1	-	1	1
	Doing more complex experiments	1	-	1	1	-	-

* H: High, M: Middle, L: Low, f: frequency

As a result of the interviews, it was seen that not all students directly accepted the information they learned as correct. While a student in the experimental group said, “Sometimes false information can be created”, a student in the control group said, “Everything we hear may not be true if the person himself/herself is wrong.” In order to ensure the accuracy of the information, each student suggested doing an experiment. The students suggested using more materials, doing complex experiments, and conducting experiments that would allow individual work.

Discussion

Recent debates on the effectiveness of inquiry-based instruction, as indicated by both PISA analysis (see Aditomo & Klieme, 2020; Cairns, 2019) have highlighted the need to investigate its effects on intended goals. To this end, this study seeks to explore the impact of guided-inquiry laboratory activities related to Matter and Change on 5th-grade students.

Effect of Guided Inquiry-Based Laboratory Activities on Research Skills of 5th Grade Students

The students in the experimental group of this study had the chance to engage in inquiry-based research activities. This gave them the opportunity to hone their research skills, which developed more than the control group students who were limited to teacher-led confirmatory activities and structured laboratory tasks.

Our findings corroborate those from other studies in the literature (Aydın, 2020; Bunterm et al., 2014; Marshall et al., 2017; Stender et al., 2018; Varlı & Uluçınar Sağır, 2019). During our study, we provided students with various materials such as resource books, tablets, and smart boards for research purposes. Additionally, the students also benefited from worksheets based on guided-inquiry experiments, which were included in their research activity due to their lack of experience in performing inquiry-based laboratory experiments (Cayvaz et al., 2020).

The teacher, the second author, informed the students that resources were available to them, but left it up to them to decide which one to use and how. They encouraged students to use these materials when doing research, particularly when designing experiments to solve a problem, to help them discuss their findings with the guidance of teachers. The goal of the teachers was to improve their students' inquiry skills and design learning activities (Stender et al., 2018) to construct effective inquiry-learning activities.

The control group had the teacher-centered approach, where the teacher presented the material, and then students completed confirmatory/structured lab activities from worksheets based on the 5th grade textbook. To still let students explore, the teacher provided resource books, tablets, and smart boards. This was similar to the experimental group.

In inquiry-based learning environments, students not only learn scientific data from teachers and textbooks, but also take part in activities that involve a set of research processes (Wu & Hsieh, 2006). However, most of the textbook activities often include structured-inquiry activities and fundamental scientific process skills, such as observing, recording data, and communicating (Bayır & Kahveci, 2021; Chakraborty & Kidman, 2022). Thus, the control group students in the experiment did not need to conduct additional research, since the worksheets provided them with the necessary information, such as the name of the experiment, its purpose, materials, and steps, and the teacher gave them an overview of the subject before the experiment.

The semi-structured interviews revealed that the students in the experimental group engaged in more research activities (such as observation, concept research, use of internet and resource books). This indicates a positive effect of guided inquiry-based laboratory activities on students' research skills.

Studies have consistently shown that inquiry-based instruction is effective in developing students' research skills (Bunterm et al., 2014; Chu, 2008; Çıtak, 2016). However, its effectiveness is dependent on how it is applied and the manner in which gains are targeted (Vorholzer & von Aufschnaiter, 2019).

Effect of Guided Inquiry-Based Laboratory Activities on 5th Grade Students' Perception of Inquiry Learning Skills in Science

The present study found that 5th grade students' perceptions of inquiry learning skills increased after engaging in guided-inquiry laboratory activities, such as those related to the Matter and Change unit. These activities proved to be beneficial to the students.

In inquiry-based learning environments, students have the opportunity to develop inquiry skills at each stage of the inquiry process. These skills include posing effective questions, creating explanations based on evidence, and applying the necessary skills to conduct the inquiry effectively (NRC, 2000; Wu & Hsieh, 2006).

In this research, the teacher guided the students through an inquiry-based process using activity worksheets for scaffolding. These worksheets were designed to help students solve problematical situations in their daily life. During the process, the teacher asked open-ended questions to encourage the students. As the students gained more experience in inquiring, the teacher gradually reduced the amount of guidance they received, allowing them to take more responsibility for their learning.

Semi-structured interview results corroborate the findings from the scale. We found that students in the experimental group asked more questions (to the teacher/friend, researching, repeating the experiment, doing an experiment) when questioning the accuracy of the information, compared to the control group, and were more skeptical before accepting it as correct or not. Student-centered learning environments foster increased interaction between students, which could improve their inquiry-related understanding and skills. This could enable them to form better questions, devise more appropriate means of seeking answers, and gather more reliable sources of data and evidence (Concannon et al., 2020).

The goal of science education is to develop students' perceptions of scientific inquiry from grades 1–12 (Eliyahu et al., 2021). Previous research has examined the effect of an inquiry-based approach on students' perceptions of inquiry learning skills (Hairida, 2016; Marshall et al., 2017; Varlı & Uluçınar Sağır, 2019; Wu & Hsieh, 2006). The results of these studies consistently showed that guided inquiry-based activities are beneficial in improving students' perceptions of inquiry skills and inquiry learning skills.

According to the data obtained from the semi-structured interviews with the students, it is seen that the students want to do more complex experiments with more materials. Being in such a learning environment may have increased their curiosity and motivation towards scientific research. So far, there has been little discussion about students’ perception of inquiry-based learning skills. Although the perceptions of science inquiry learning of secondary school students (Saraçoğlu & Kahyaoğlu, 2018) and undergraduate students (Mistry & Gorman, 2020) were low, Saraçoğlu and Kahyaoğlu pointed to a positive relationship between the perceptions of scientific inquiry skills of secondary school students and their affective characteristics, such as curiosity and motivation.

The semi-structured interviews with students revealed that those from the experimental group desired to do more complex experiments with more materials. This indicates that the learning environment has increased their curiosity and motivation towards scientific research. In addition, there has been research on the perception of inquiry-based learning skills among secondary school and undergraduate students (Mistry & Gorman, 2020; Saraçoğlu & Kahyaoğlu, 2018;). Saraçoğlu and Kahyaoğlu found that the perceptions of scientific inquiry skills of secondary school students had a positive relationship with their curiosity and motivation levels. Meanwhile, Mistry and Gorman indicated that the perceptions of inquiry-based learning skills among undergraduate students were low.

We found that the students in the experimental group had difficulty using various skills such as hypothesizing, designing experiments, collecting data, and identifying and controlling variables. Similar findings have been reported in the literature (e.g., Durmaz & Mutlu, 2017; Stender et al., 2018). The students reported that they had no prior inquiry-based learning experience, which likely contributed to their difficulty in adapting to the process and using the necessary skills.

Szalay, Tóth, and Kiss (2020) followed the same students for two years, and found that there was no significant change in the experimental design skills of 12- to 13-year-olds, who had not been exposed to either structured or guided inquiry activities. In contrast, Lazonder and Harmsen's (2016) meta-analysis showed that students' experimental design skills improved with age. This discrepancy suggests that further research is needed to draw a more definitive conclusion.

Educational Implications

The present study provides evidence supporting guided-inquiry laboratory activities as more effective in improving 5th grade students' research skills and the perceptions of inquiry learning skills of science compared to teacher-centered confirmatory and/or structured laboratory activities.

The laboratory is an important component in science education, and plays a key role in developing inquiry skills (Hofstein & Kind, 2012). From this vantage point, considering the existing Turkish 5th grade science curriculum, guided-inquiry activities can be successfully performed for the unit of Matter and Change in either a laboratory or a classroom environment.

As a result, we can state that it is important to provide opportunities for longer-term practical experience and to provide instructional guidance at earlier grade levels in order to develop the students' inquiry-research skills.

Conclusion

In the present study, we aimed to investigate the effects of guided inquiry-based laboratory activities related with the Matter and Change unit on the perceptions of research skills and inquiry learning skills of science of 5th grade students. Although this study had some limitations, such as small sample size and lack of analysis of the long-term students' outcomes of research and inquiry learning skills, it revealed the potential of the guided inquiry-based laboratory activities in enhancing the students' research and inquiry learning skills. We think that the materials or activities in the textbooks can be redesigned in line with the targeted acquisitions. Therefore, when guided inquiry-based laboratory activities are purposively incorporated into a science course, the research and inquiry learning skills of students can be gradually improved over time. Additionally, guided inquiry-based laboratory activities can be seen as a transition to open inquiry level activities for science courses.

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Notes

1. This study consists of part of the Master's thesis prepared by Medat Mutlu at Trakya University, Institute of Science. In addition, one part of this study was presented at the ERPA 2021 International Congress on Education.
2. The study was approved by the Kırklareli Governorship Provincial Directorate of National Education with the authority approval dated 22 October 2019 and numbered 20684216; and then by the Institute of Natural Science, Trakya University with the authority approval dated 1 December 2019 and numbered 48037873-44. Participation in the study was voluntary. After receiving permission, all participants and

their parents were informed about the study content. Parents had to sign an informed consent form for their children to participate.

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Medat Mutlu is a science teacher and interested in inquiry-based science education for elementary school students.

Appendix A: Activity Worksheet for Experimental Group

Name of the Activity: Mother's Day Celebration

Ali Kerem wants to make a special gift for his mother for Mother's Day. For this, the course where various handmade gifts are made is a unique opportunity. He thought that the course teacher could help him with this. The next day, at the course, he spoke to his teacher about it. He wanted to make candles in various shapes. For this, his teacher brought him a large candle and molds of various shapes. The teacher did not give Ali Kerem any sharp tools that could be dangerous. For this reason, Ali Kerem would not be able to cut the candles. Ali Kerem was confused and asked his teacher: 'Teacher, this candle is huge. How can I make small candles in different shapes using this candle and the molds you provided?'. The teacher told Ali Kerem that if he thought a little, he could solve this problem.

Defining problem: What is the problem Ali Kerem is trying to solve in the text you read?

- ➢

Forming hypothesis

How can Ali Kerem solve this problem?

- ➢

Designing experiments

How do you plan an experiment to test the solution to Ali Kerem's problem?

- ➢

You can use the following materials for the experiment you planned. If there are materials you want to use other than the ones given, write them too:

- ➢

Materials that can be used: alcohol burners, a tripod stand for alcohol burners, wire mesh, tongs, a candle, silicone molds in different shapes, a beaker, ice, a weighing machine.

- ➢

Experiment

Write down your observations and data in detail by doing your experiment.

-

Fill in the table below regarding the initial state of the candle.

Color	Physical State	Image	Mass

What process did you apply to pour the candle into the mold?

-

Fill in the table below regarding the state of the candle as a result of the process you applied.

Color	Physical State	Image	Mass

What process did you apply after pouring the candle into the mold?

-

Fill in the table below regarding the state of the candle as a result of the process you applied.

Color	Physical State	Image	Mass

Interpreting the results

What conclusion do you draw based on your observations?

-

Did the data you obtained support your initial hypothesis? What is your evidence for this?

-

Define the concepts you learned through the experiment in your own words.

-

Appendix B: Activity Worksheet for Control Group

Name of the Activity: Melting-Freezing

Objective of the experiment: Observing that substances can change their state under the influence of heat.

Materials: Alcohol burners, a tripod stand for alcohol burners, wire mesh, tongs, a candle, silicone molds in different shapes, a beaker, ice, weighing machine.

Experiment:

Do the experiment by following the instructions below:

1. Put a piece of candle in the beaker.
2. Put the alcohol burner under the tripod stand and turn on the alcohol burner carefully.
3. Place the beaker on the tripod.
4. Let the wax become liquid and observe the melting.
5. Pour the liquefied wax into silicone molds.
6. Place the molds in the ice-filled container.
7. Let the candles solidify and observe the freezing.

Results: Write down your observations.

- ➢

Conclusions:

- ➢