Effect of Inquiry-based Laboratory Approach on Scientific Process Skills, Critical Thinking Skills, and Opinions of Ninth Grade Students: Cell Unit Example

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Abstract

This research aimed to investigate the effect of the inquiry-based laboratory approach on the science process and critical thinking skills of 9th-grade students as well as opinions about the approach. The study was designed according to the case study research model. The research was conducted with 56 students, 28 in the experimental group and 28 in the control group, studying at a high school. While the lessons in the experimental group were carried out with the inquiry-based laboratory approach, the subjects were carried out according to the current teaching in the control group. Science Process Skills Test, Critical Thinking Disposition Inventory, and Semi-Structured Interview Form were used as data collection tools. Data were analyzed both through inferential and content analysis. As a result of the research, the inquiry-based laboratory approach effectively improves ninth-grade students' science process skills and critical thinking dispositions. In addition, the inquiry-based laboratory approach enabled students to be successful in subjects such as active participation in the lesson, obtaining permanent information, creating information themselves, group work, and experimenting. An inquiry-based laboratory approach to various topics is recommended, and teachers should be trained in it.

Keywords: Science Education, Biology Education, Inquiry-based Laboratory Approach, Science Process Skills, Critical Thinking

INTRODUCTION

Biology education helps students gain scientific thinking skills and solve problems they encounter with positive attitudes and approaches. In this context, biology education aims to raise biology-literate individuals who love biology and enjoy the course. This aim is realized through the biology course taught in secondary education (Ministry of National Education [MoNE], 2018). Teachers have an essential role in students' knowledge discovery in biology lessons. Teachers have the task of preparing learning environments by the level of students. One of these duties of teachers is to guide students to design experiments, conduct research, establish hypotheses, test hypotheses, change hypotheses, work like scientists, and share the information they collect with other students. As in many lessons, laboratories have particular importance in students' learning in biology lessons (Khan, 2012).

The lessons held in the laboratory contribute to the scientific purpose, encouraging students and providing them with an idea about the work of scientists (Aliefman et al., 2022). In addition, laboratories help students research, design, and practice experiments and reach the results of the problem (Bilen et al., 2011). In addition, laboratories are practical for students to gain positive attitudes toward science and understand principles and concepts with concrete experiences. Laboratory-assisted biology teaching contributes to students' liking the lesson, having fun, and developing positive attitudes toward the lesson (Röllke et al., 2021). Therefore, it is thought that laboratory-supported learning environments will contribute to students' science processes and critical thinking skills. Therefore, it is believed that this study will contribute to the literature regarding the effect of the inquiry-based laboratory approach on ninth-grade students' science process and critical thinking skills.

Inquiry-based Laboratory Approach

The inquiry-based laboratory approach is based on Bruner's student-centered teaching-learning theory. With this teaching approach, principles, concepts, and generalizations are learned through the experiments the students plan, thus keeping the students' curiosity alive. It has been observed that the students in the learning environment in which this approach is used have high cognitive and affective characteristics. Students can conduct research, design experiments, form hypotheses, and discover knowledge through the inquiry-based laboratory approach. In addition, students gain the skills of scientists, such as participating in group work, sharing information, and questioning. It can be said that this approach is practical in training future scientists (Erdem & Alkan, 2015).

In the inquiry-based laboratory approach, the students are the practitioners at the center, and the teacher is the guide. This approach includes "research, inquiry, questioning, discussion, creation, and reflection". Therefore, it is essential to ask questions. The teacher should prepare before the lesson and focus the students on the study by preparing well-structured questions that focus the students on the study. These questions should attract attention, build a bridge between old and new knowledge, develop a sense of achievement, and encourage the desire to do research by improving the questioning skills of the individual. The questions asked should appeal to all students. If the question asked cannot attract the attention of all students and focus on the subject, some students may not learn. Therefore, the teacher should prepare the questions sensitively and be flexible enough to change them if necessary (Ditzler & Ricci, 1994).

According to this theory, the teacher does not convey the ready-made information directly but presents the problem to the student. Left alone with the problem, the student learns the subject while searching for a solution. In order to increase the effectiveness of this approach, the topics to be covered should be at the general and student level (Rahmatika et al., 2022). The student who organizes the experiment should find the answer due to his research and not knowing in advance. Students who encounter a problem during the experiment should create the solution themselves. In order for this method to give the desired result, the subject given to the students should be wide-ranging, the organization of the experiment should be left to the students, and they should be guided on how to relate the results they found to their daily life (Artun et al., 2020). In this laboratory approach, students need to learn scientists' characteristics and feel like scientists in the laboratory environment. In this context, it is thought that revealing the effect of the inquiry-based laboratory approach on ninth-grade students' science process skills and critical thinking will contribute to the literature.

Science Process Skills

Science process skills are the skills that actively involve students in the process, provide ways and methods to be used during research, approach problems with a scientific perspective, facilitate learning and provide permanent learning, and develop the sense of taking responsibility for their learning (Acarli & Dervişoğlu, 2021). Since science process skills are essential to mental development and are used in daily life, students must acquire them. Science process skills are the essence of science. In addition, these skills contribute to the development of student's ability to conduct research and draw conclusions from their studies (Syahfitre et al., 2019; Berlian et al., 2023). These skill steps are classified as making observations, forming hypotheses, planning the research, interpreting the findings, reaching the results, and sharing the results (Acarli & Dervişoğlu, 2021; Şimşek, 2010). Science process skills include learning these steps, comprehending the nature of science, and transferring it to life (Khan & Iqbal, 2011; Ping et al., 2019). Therefore, it was wondered whether the students who use science process skills in the learning environment affect their critical thinking skills. This study aimed to determine the effect of the inquiry-based laboratory approach on the critical thinking of ninth-grade students. It is believed that the result to be obtained will contribute to the studies to be carried out on this subject.

Critical Thinking

McLeod et al. (2015) stated that American educator, philosopher, and psychologist John Dewey is the father of modern critical thinking education. It was reported that Dewey defines critical thinking as "evaluating any belief or knowledge in an effective, permanent and careful way, together with the reasons supporting it and other related consequences". There are three parts to critical thinking. These are asking questions, analyzing, and believing the result. Critical thinking requires asking good questions that go to the subject's core, trying to understand the logic of these questions, and believing the results are a criterion of critical thinking (Facione, 2011). Today, since information is easily accessible, it has become inevitable to make applications different from ordinary methods to develop original ideas, think critically, organize information, create solutions to problems, and support creativity (Chen & Chuang, 2021). From this point of view, using the inquiry-based laboratory approach in biology teaching and determining its contribution to students' critical thinking skills make this study significant.

Opinions

When the studies conducted in education are considered in general, it is seen that studies investigating the effectiveness of learning activities prepared for teaching a specific subject have an essential place (Leblebicioglu et al., 2017). In these studies, student groups are provided to experience learning activities. In addition, students have the opportunity to develop skills such as scientific process skills and critical thinking skills, which are focused on in research. For this reason, the opinions of students affected by the learning process about the subject, skill, or the process itself become important (Murphy et al., 2021). In this study, students’ opinions about the learning process were tried to be revealed.

Importance of Research

An inquiry-based laboratory approach is one in which students are active at every teaching stage. For this reason, it is thought that this laboratory approach will facilitate learning abstract and complex subjects in biology teaching, help students establish a relationship between biology lessons and daily life, and help teachers. In this teaching approach, it can be said that students’ following scientific research methods like a scientist will increase their learning motivation and the realization of permanent learning. Today, providing students with science processes and critical thinking skills at every education level is essential. In particular, gaining science process skills early is important in students’ 21st-century skills at the later education level (Chen & Chuang, 2021; Syahfitre et al., 2019). In this context, it has become essential to reveal the effect of the inquiry-based laboratory approach on ninth-grade students' science process and critical thinking skills. Thus, it is anticipated that the results of this study will contribute to future studies. Therefore, the primary purpose of the research is to examine the effect of the inquiry-based laboratory approach on ninth-grade students' science process skills and critical thinking skills.

METHOD

Research Design

In this study, the case study method was adopted to reveal the effects of an inquiry-based laboratory approach on science process skills, critical thinking dispositions, and student opinions. The case study method allows for the simultaneous study of the quantitative and qualitative dimensions of the research topic. A test and an inventory were applied in the quantitative part of this study. In the qualitative part, an interview was conducted to reveal student opinions. Thus, it has become possible to determine the students’ views about the learning process without any generalization concerns (Çepni, 2021).

Participants

The study sample was determined as an easily accessible sampling method (Çepni, 2021). The research was conducted with 56 ninth-grade students in a high school in the Eastern Anatolia region. After the learning procedure, semi-structured interviews were conducted with ten students selected from the experimental group. The characteristics of the experimental process of the study are given in Table 1.

Table 1 Research Process

Groups	Pre-test	Implementation	Post-test
Experimental	Science Process Skills Test, Critical Thinking Skills Inventory	Inquiry-based Laboratory Approach	Science Process Skills Test, Critical Thinking Skills Inventory Semi-structured interview
Control	Science Process Skills Test, Critical Thinking Skills Inventory	Using the current biology curriculum	Science Process Skills Test, Critical Thinking Skills Inventory

Data Collection Tools

This research used the Science Process Skills Test, Critical Thinking Dispositions Inventory, and Semi-Structured Interview.

Science Process Skills Test

The test was initially developed by Burns et al. (1985) and translated into Turkish by Aktamış (2007). The test aimed to measure the basic science process skills of students, such as recognizing and making sense of the variables in the problem, forming and testing hypotheses, drawing data in graph form, interpreting the data, making operational explanations, researching for the solution of a problem, collecting data, and designing research. The test's reliability coefficient (KR-20) was determined as 0.89 (Aktamış, 2007).

California Critical Thinking Disposition Inventory

The inventory was developed for the Delphi project in the USA in 1990. Since the study was conducted with Turkish students, the Turkish version of the inventory adapted by Kökdemir (2003) was used. There are seven sub-dimensions and 75 items in the original inventory. The original sub-dimensions of the scale were listed as truth-seeking, self-confidence, open-mindedness, systematicity, analyticity, maturity, and curiosity (Kökdemir, 2003). As a result of the studies, the internal consistency coefficient (alpha) of the new inventory, which was reduced to a total of 51 items and six dimensions, was found to be 0.88. The Cronbach's alpha value of the inventory for the sample in this study was found to be 0.80. The lowest score that can be obtained from the inventory is 60, and the highest score is 360.

Semi-Structured Interview

Qualitative data were collected with a semi-structured interview form. A semi-structured interview form was preferred so that the participants could express their views more sincerely and authentically (Yıldırım & Şimşek, 2013). In line with the purpose of the study, seven questions were prepared by the researchers. The questions in the interview form were submitted to the examination of three experts in the field of science education. After examining the experts, two questions were removed from the interview form. These questions were removed from the interview form because they do not serve the purpose of the research, and their contents are similar. The final version of the interview form consists of five questions and is given below.

Learning Procedure

This study lasted six weeks in the experimental and control groups (two hours per week, for 12 hours). During the learning procedure, the same teacher conducted the lessons in the experimental and control groups. In the control group, lessons were carried out according to the inquiry-based learning approach, and in the experimental group, according to the inquiry-based laboratory approach. In the experimental and control groups, the Science Process Skills Test and the California Critical Thinking Disposition Inventory were administered as a pre-test before the application. The activities developed by the researchers were applied to the experimental group within the scope of the inquiry-based laboratory approach. At the end of the application, the Science Process Skills Test and the California Critical Thinking Disposition Inventory were administered to the experimental and control groups as a post-test. In addition, a semi-interview was held with the participation of 10 students from the experimental group. A section of the applications in the experimental and control groups is explained below.

Learning Procedure in the Experimental Group

The lessons were taught according to the inquiry-based laboratory approach. Unlike the control group, five different laboratory activities prepared by the researchers according to the inquiry-based laboratory approach were used in the experimental group. These activities applied in the experimental group as "Differences Between Animal Cell and Plant Cell", "Differences Between Prokaryotic Cell and Eukaryotic Cell", "Interaction of Cell and Solutions of Different Density", "Plasmolysis and De-plasmolysis Events", and "Creating Animal Cell Models". In these activities, students were arranged in groups of four, each time with different friends. The researcher guided the students, answered their questions, and supported them.

Introduction: The teacher helped students make predictions based on their laboratory knowledge. In each of the activities, the main concepts related to the work they will do were expressed to the students. For example, for the “Creating an Animal Cell Model” study, the students were given information about the parts of the cell and the shapes and positions of the organelles in the cell. It is explained what should be considered when creating animal cells.

Inquiry: In each activity, the researcher guided students to enable them to make predictions based on their knowledge and to support them. The researcher explained the necessary information in the experiment’s preparation, design, and maintenance and asked questions. The students’ attention was drawn to the subject by asking questions, such as the teacher providing information about the solution that learning the subject would bring to the students’ use in daily life the solution to the problems, and their motivation towards the lesson was ensured. Then, the teacher distributed the experiment materials to the groups. The teacher asked the students to take samples from the leaves in their hands and the cells inside their cheeks and examine them under a microscope. The students formed hypotheses according to the examination results, the groups tested the hypotheses, and all the results were discussed with the students.

Evaluation: At this stage, the students discussed whether they would conclude after completing the experiments. For example, In the experiment “Comparing animal cells with plant cells”, the students concluded that “the shape of plant and animal cells is different, and this is because plant cells have a cell wall”. The students realized that because plant cells have a cell wall, they are polygonal and angular. On the other hand, they noticed that animal cells have a spherical shape because they do not have a cell wall. In addition, the students learned that animal cells are colorless and plant cells are green because they contain chloroplasts. For example, they were asked to write down what they would pay attention to if they were given a chance to make a model of an animal cell model again. Finally, the researcher evaluated whether the students could access information with the questions asked. The answers to these questions were put forward by having group discussions with students.

Learning Procedure in the Control Group

The control group taught the lessons according to the inquiry-based learning approach. The 9th Grade Biology textbook of the Ministry of National Education was used as a source.

The inquiry-based learning approach was handled in three steps.

Introduction: The students' attention was drawn to the subject by asking questions such as: "Which organelles are found in animal cells?", "What is the organization like in animal cells?", "What are the functions of organelles?" and "Are there structures found in animal cells that are not found in other cells?". Students' answers to the questions were written on the board. The teacher posed some new questions to find out the vague answers of the students and to reveal the students' preliminary knowledge of the subject. For example, the teacher asks the class, "What is why animal cells are not colored while plant cells are green?". Similarly, the teacher asked the class, "How do you explain the polygonal shape of the plant cell while the animal cell is spherical?". Finally, the teacher asked them to form their hypotheses on the subject in light of their answers.

Inquiry: Activities such as "Let's Create an Animal Cell", "Let's Create a Plant Cell", and "Let's Find the Differences Between Plant and Animal Cells", which were adapted from the biology textbook, were distributed to the students in the form of worksheets. The class was divided into four groups, and the necessary materials were distributed to each group. They were first asked to fill in the estimation section in the worksheet. The groups were then asked to complete the exercises.

Evaluation: The information obtained as a result of the activity was compared. It was observed that the students completed their studies thanks to the cooperation in the groups. The activities in the worksheets were repeated with the students. The students seemed to have learned the similarities and differences between plant and animal cells.

Data Analysis

The data collected with data collection tools of the study was homogeneous and showed a normal distribution. Then the eta-square (η^2) coefficient was calculated to determine the effect levels. It is an indicator of the power of the effect of the independent variables on the dependent variable, which is one of the variables that the assumption of linearity does not require. The η^2 ranges from .00 to 1.00. The η^2 values at .01 are interpreted as "small", .06 as "medium", and .14 as "large" effect sizes, respectively, and explain the total variance of the independent variable in the dependent variable. (Büyüköztürk, 2019).

Lastly, the data obtained through the semi-structured interview were analyzed with the content analysis method. Content analysis was preferred so that readers could better understand the data (Yıldırım & Şimşek, 2013). Participating students were coded as S1, S2, S3, …. S10. The researchers transcribed interviews with the participants. Researchers individually created themes, categories, and codes. Then, the researchers came together and compared the themes, categories, and codes they created and determined the compliance rate. Miles et al. (2020) proposed a reliability formula to calculate this compliance rate. The study determined the consistency reliability coefficient among the coders to be 85%. This calculated value shows that the coding made in qualitative studies is reliable. Themes, categories, and codes obtained from the analysis are presented in Table 1, Table 2, Table 3, Table 4, Table 5, Table 6, Table 7, and Table 8.

RESULTS AND DISCUSSION

As a result of the data analysis, the findings about the participants' scientific thinking skills, critical thinking skills, and opinions on the inquiry-based laboratory approach are presented in this section.

Findings from the Scientific Thinking Skills Test

The data obtained from the test was used to compare the experimental and control groups before and after the application to make a comparison between the scientific process. Since the data showed normal distribution, a t-test was preferred. The findings of the t-test result between the pre-post-test scores of the experimental and control group students' science process skills are given in Table 2.

Table 2 Comparison of Experimental and Control Group Students' Science Process Skills

Test	Group	N	X	SD	Df	t	p
Pre-test	Control	28	58.70	3.15	54	1.2519	0.216
	Experimental	28	57.60	3.42			
Post-test	Control	28	74.63	2.82	54	17.5709	0.001
	Experimental	28	87.10	2.48			

When the table is examined, it is understood that the comparison made between the experimental and control groups in terms of scientific process skills test scores before the application does not indicate a statistically significant difference ($t(54)=1.2519$, $p>0.05$). The comparison made after the application indicated a statistically significant difference ($t(54)=17.5709$, $p<0.05$). In addition, after the application, the control group's average was 74.63, while the average of the experimental group was 87.10, indicating that the difference was in favor of the experimental group. Thus, inquiry-based laboratory teaching was more successful than traditional inquiry in increasing students' scientific process skills.

Findings from the Critical Thinking Disposition Inventory

The data obtained from the inventory was used to compare the critical thinking skills of the experimental and control groups after the application compared to before the application. The findings obtained from the t-test conducted to compare the groups in terms of critical thinking before and after the application are given in Table 3.

Table 3 Comparison of Experimental and Control Group Students' Critical Thinking

Test	Group	N	X	SD	df	t	p
Pre-test	Control	28	172.95	20.01	54	0.7186	0.475
	Experimental	28	176.82	20.29			
Post-test	Control	28	223.23	21.82	54	5.6251	0.001
	Experimental	28	190.83	21.28			

When the Table 3 is examined, it is understood that the comparison made between the experimental and control groups in terms of critical thinking before the application does not indicate a statistically significant difference ($t(54)=0.7186$, $p>0.05$). It was determined that the comparison made after the application indicated a statistically significant difference ($t(54)=5.6251$, $p<0.05$). In addition, after the application, the control group's average was 223.23, while the average of the experimental group was 190.83, indicating that the difference was in favor of the experimental group. Thus, inquiry-based laboratory teaching succeeded more than traditional inquiry in increasing students' critical thinking skills.

Findings from semi-structured interviews

Themes and codes were created according to the answers from the experimental group students participating in the research to the questions in the semi-structured interview form. The findings are given in tables.

Experimental group students' "What are your thoughts on teaching biology based on the inquiry-based laboratory approach?" The codes obtained from the answers to the question are given in Table 4.

Table 4 Thoughts on Biology Teaching with an Inquiry-based Laboratory Approach

Theme	Codes	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Inquiry-based Laboratory Approach	Making learning easier	+	+	+	+	+	+	+	+	+	+
	Fun-enjoyable	+	+	+	+	+	+	+	+	+	+
	Permanent learning	+	-	+	+	+	-	+	-	+	+
	Stay engaged with the lesson.	-	+	+	-	+	+	-	-	+	-
	Concretizing abstract issues	+	+	-	+	-	-	-	+	+	-
	Avoiding rote	+	-	+	-	-	+	+	-	-	-
	Laboratory experience	+	-	+	-	-	-	-	-	+	+
	Active participation	+	+	-	-	-	+	+	-	-	-
	Group working experience	-	+	-	-	-	+	+	-	-	-

When Table 4 is examined, it is seen that the experimental group students found the biology lessons taught with the method of inquiry-based laboratory approach fun; they did not get bored with the lesson, they learned by living in experiments carried out with laboratory experience, they provided permanent learning by preventing memorization, they concretized the subjects and their group work strengthened their communication with their friends. Below are some student opinions about the first theme.

"At first, it was gratifying. I think it is more effective in terms of learning as well. Because the things said in training can sometimes be forgotten, but I do not think we will forget the experiments we did. We also experienced how experiments can be done in a laboratory environment or what we should or should not do in a laboratory environment (S1)."

"I think it is better because we learn by doing ourselves, which will allow me to keep the information in my mind longer and increase my ability to understand, so I think understanding by doing is better than memorizing. It was also gratifying to work with our friends in the group for a common result and to do research (S7)."

The students in the experimental group asked, "What do you think are the things you like about teaching biology with the inquiry-based laboratory approach?". The answers to the question are given in Table 5.

Table 5 Thoughts on liked aspects of the inquiry-based laboratory approach.

Theme	Codes	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Group work	Team spirit	+	+	+	+	+	+	+	+	+	+
	The teacher is a guide.	+	-	-	+	-	-	+	-	+	-
	Focus on a common goal.	+	-	-	-	+	+	-	-	-	+
	We determine the outcome.	+	+	-	-	+	-	-	+	-	-
Laboratory use	Experiment	+	+	+	+	+	+	+	+	+	+
	Teaching in the lab	+	+	+	+	+	+	+	-	+	+
	Using a microscope	+	-	+	-	+	-	-	-	-	+
	To observe	-	+	-	-	+	-	-	+	-	-
	Interacting more with the teacher	+	-	+	-	-	-	-	+	-	-

The codes were created under the theme of group work, acting with a team spirit, the teacher not interfering with the groups formed but only advising, the groups struggling to reach the result, and the students determining the results. Some students' opinions about these codes are given below.

"There are several points that I like. One of these points is to conduct a group experiment with the guidance of our teacher and complete this experiment and get a successful result (S1)."

"I also liked creating a team environment because it is one of the points I like. We get help from each other when we need to act together with our teacher and friends in this environment, not alone (S10)."

For the theme of laboratory use, there are codes for experimenting, observing, doing research, using a microscope, teaching the lessons in a more scientific environment, not in the classroom, but in a more scientific environment, active participation, and interacting with the teacher more than in the classroom. One of the answers to this question given by the students is given below.

"I enjoyed experimenting and studying. The lessons were more productive and permanent for me. I saw a microscope in secondary school but learned to use it this year. I liked it very much; we all got experience using the microscope. In addition, we made great efforts to reach the results and conducted research and observations (S5)."

Experimental group students asked, "What are your thoughts on teaching biology subjects with the inquiry-based laboratory approach increasing the students' academic success?" The answers to the question are given in Table 6.

Table 6 Opinions on the effect of inquiry-based laboratory approach on academic success

Theme	Codes	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Effects on Academic Success	Increasing success	+	+	+	+	+	+	+	+	+	+
	Active learning	+	+	+	+	+	-	-	-	+	+
	Avoiding rote	+	+	+	+	-	+	-	+	-	+
	Contribution to the future	+	-	-	+	+	+	-	-	-	+
	Remember the results.	-	+	-	+	+	-	-	-	+	+
	Increase in exam grades	-	-	-	-	+	+	+	+	-	+
	Putting theory into practice	+	-	-	-	+	+	+	-	-	-
	Learning by doing	+	-	+	-	-	-	+	-	-	+
	Gain experience	-	+	+	-	-	-	+	-	-	-

The inquiry-based learning approach: to increase success, to learn by doing, to provide effective learning, to create an experience, to prevent memorization, to contribute to the future, to increase exam grades, to keep the knowledge obtained as a result of the experiments and to transfer the theoretical knowledge into practice. One of the answers to this question given by the students is given below.

"In my opinion, it increases because the student will understand biology better here, which will be reflected in his exam grades and ensure that his grades are better. In addition, his good academic achievement will enable him to be more successful in the future." (S4)

Experimental group students asked, "What are your ideas about the inquiry-based laboratory approach to help students gain the ability to do research?" The answers to the question are given in Table 7.

Table 7 Opinions on the effect of the inquiry-based laboratory approach on the ability to do research

Theme	Codes	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Ability to do research	Research request	+	+	+	+	+	+	+	+	+	+
	Source scanning	+	-	+	-	-	-	+	-	+	+
	Creating a sense of curiosity	+	-	-	+	+	-	-	+	-	-
	Reaching the conclusion	-	+	-	+	-	-	+	+	-	-
	Problem-solving	-	+	-	-	-	+	+	-	-	+
	Using a microscope	+	-	+	-	-	+	-	-	-	-
	Increasing interest in life	-	-	-	+	-	-	-	+	-	-
	gain experience	-	-	-	+	-	-	+	-	-	-

It is seen that the inquiry-based laboratory approach contributes to students' ability to conduct research. Students expressed their views on this subject with the codes of desire to research, creating a sense of curiosity, using a microscope, increasing interest in living things, solving problems, reaching conclusions, and literature review. One of the answers given by the students is given below.

"I think it has increased our research capability. First, it makes us want to research the experiment we will do. Because it makes us want to have information about what we will encounter in the laboratory environment, while researching this, a sense of curiosity arises in various subjects, thus increasing the desire to research (S1)."

Experimental group students asked, "When you compare biology teaching based on the inquiry-based laboratory approach with the current teaching, can you explain which approach you learned better?". The answers to the question are given in Table 8.

Table 8 Opinions on comparison of the inquiry-based laboratory approach with the current approach

Theme	Codes	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Inquiry-based Laboratory Approach	Students being active	+	+	+	+	+	+	+	+	+	+
	Increasing interest in the lesson	+	+	+	+	+	+	+	+	+	+
	Permanent learning	+	+	+	+	+	+	+	-	+	-
	The lesson is not dull.	+	+	+	-	+	-	+	+	-	+
	Gaining a different perspective	-	+	-	+	-	-	+	-	-	-
	Hands-on learning	+	-	+	-	-	+	-	-	-	-
Current Approach	Inability to remember	+	-	+	-	-	+	-	-	-	+
	Inability to do group work	+	-	-	+	-	+	+	-	-	-
	Inability to embody the subject	+	-	-	-	-	+	-	+	-	+
	The teacher is active.	+	-	+	-	-	-	+	-	-	-
	Inability to focus	+	-	-	+	-	-	-	-	+	-

The students explained the codes of the inquiry-based laboratory approach as the students being active, the course not being boring, applied learning, permanent learning, keeping the interest in the course fresh, and gaining different perspectives.

The codes created for the learning theme with current teaching include being unable to remember quickly, forgetting quickly, repeating a lot, not concretizing the subject, not forming groups, and realizing teacher-centered teaching. S9 explained these codes: "I think it is better because it is based on observation and review. The laboratory method was fun and efficient compared to the method we used in the classroom”.

A significant difference was found between the experimental group's pre-test and post-test scores on the Science Process Skills Test in favor of the post-test. It is thought that using science process skills in teaching biology based on the inquiry-based laboratory approach is effective in developing the students in the experimental group. For example, in the activity on differences between animal cells and plant cells (Activity 1), it can be said that students’ basic process skills, such as observing, classifying, communicating, making predictions, and drawing conclusions, are included. At the same time, the interaction of cells and solutions of different densities (Activity 3) is thought to develop students’ scientific process skills such as observing, communicating, classifying, measuring, estimating, and drawing conclusions. When the studies on this subject in the literature are examined, it has been concluded that laboratory-supported teaching positively affects scientific process skills (Gunawan et al., 2019). Yurdatapan’s (2011) research aimed to determine whether problem-based laboratory activities affect students’ scientific process skills, self-confidence, and self-efficacy while conducting experiments in biology laboratories. In addition, a significant difference was found between the control group's science process skills test pre-test and post-test scores in favor of the post-test. This increase can be explained by including science process skills in the Biology Curriculum. When the literature was examined, it was observed that there was an increase in the science process skills post-test of the control group in some previous studies. Dolapcioglu and Subasi (2022) found a significant difference in the control group's science process skill test post-test in their study. In their study, Kanlı and Yağbasan (2008) determined that activities centered on the 7E model significantly developed students’ science process skills. At the end of the study, a significant difference was found in favor of the experimental group when the experimental and control groups' science process skills post-test scores were compared. This finding can be explained as the practices performed in the experimental group were more effective in science process skills than in the control group. For example, Yücel (2019) found a significant difference in favor of the experimental group in terms of academic achievement, scientific process skills, and attitude toward science lessons between the groups according to the pre-test and post-tests of teaching using tools and equipment in the laboratory. As a result of the study, an increase in the science process skills of the experimental group was determined.

The significant increase in the scores of the experimental group students from the critical thinking dispositions after the application shows that the inquiry-based laboratory approach activities positively affect the students' critical thinking dispositions. In the inquiry-based laboratory approach, students discuss and conclude the experiments in groups, and the practice teacher allows students to make oral presentations in their classes and the applied activities keep the student in the foreground; they discuss the subject by forming a group during the activities, they learn by doing and experiencing, they do research, ask questions, create solutions and construct knowledge. Since laboratory courses with experiments are research-based, students are expected to form hypotheses based on a problem and test their hypotheses. When scientific methods are followed and used, finding results with scientific value, even though there are different alternatives for solving problems, and reaching the result enables students to develop their critical thinking dispositions. When the literature is examined, it can be said that many previous studies have resulted in significant results in the post-tests of the experimental group students regarding critical thinking skills (Lamichhane & Karki, 2020). For example, Kırıktaş and Çoban (2016) observed that candidates' critical thinking skills improved after biology laboratory activities using multiple intelligence-supported inquiry applications. In the same vein, Yalçınyiğit (2016) found a significant difference between the attitudes of students with medium and high critical thinking skills towards the course in his research based on problem-based learning. Besides, there was no significant difference between the post-test scores of the critical thinking disposition scale of the experimental and control groups. This result shows that the ninth-grade students' critical thinking disposition scores are close to each other due to the applications in the experimental and control groups. This is an undesirable result for the study. When Gültepe (2011) compared the students' critical thinking post-tests as a result of her study, she stated that there was no statistically significant difference between the experimental and control group students.

The participants' opinions were revealed through the interview questions to reflect the inquiry-based laboratory approach during the research. The students stated that they found the biology lessons taught with the laboratory approach based on invention fun, did not get bored with the lesson, and were allowed to learn by doing and experiencing. The students explained that they provided permanent learning by preventing memorization, concretizing the subjects, and working in groups to strengthen their communication with friends. Experiencing a global epidemic during the study, the compulsory interruption of face-to-face education and the transition to distance education caused a decrease in the student's motivation. In addition, it is thought that inquiry-based laboratory approach positively affects students' science process skills and critical thinking dispositions. Students emphasized points such as acting with their friends and the teacher being only a guide. The fact that the students are constantly active during the lesson and that they continue it themselves increased their interest in the lesson and the effect of the applied method. All of the students stated that the method applied increased their academic success. They stated that they have advantages such as practical learning, preventing memorization, learning by doing, gaining laboratory experience, and contributing to their future. The students stated that thanks to these activities, they constantly researched, learned the steps of problem-solving and experimentation, got to know the microscope and learned to use it, and could search the literature. It was observed that the results obtained in this study are similar to those of the previous studies. For example, Gobaw and Harrison (2016) concluded in their study that laboratory-assisted biology teaching increases academic achievement in high school students. In a similar study, Nasution (2018) stated that there was a significant difference in the academic achievement of the experimental group students due to their studies investigating the effect of inquiry-based activities on science teaching. Aksaray et al. (2015) stated that teaching the subject of meiosis in the 10th-grade biology lesson with the laboratory method increases the permanence of the information and the interest in the lesson. According to Bruner, children naturally desire learning and research, and teachers should guide them well (Özer, 2005). In another study, Kapak (2018) emphasized that students' research skills improved as a result of his study, which is in line with the results of our study. Thus, the participants' opinions, similar to the previous studies, support the results of the positive effects of the Inquiry-Based Laboratory Approach, including the science process skills and critical thinking dispositions.

SUGGESTION

This research benefited from the Inquiry-Based Laboratory Approach. The effect of laboratory methods can be revealed by conducting studies with other laboratory methods.

Since biology lessons become more fun with laboratory applications and increase the permanence of knowledge in students, teaching in laboratories in schools should be widespread.

In our study, an inquiry-based laboratory approach was used. Studies can also be carried out with other laboratory methods.

This research was conducted with the ninth-grade Cell unit. It is possible to work with other units of the biology course at different teaching levels.

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