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Effect of Open Inquiry Based Learning Approach on the Conceptual Understanding of Secondary School Students

Research Article

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ABSTRACT

In this study, the effect of open inquiry based learning (OIBL) approach on students' conceptual understanding was investigated. Quasi-experimental research design with pre-test and post-test control groups was used as research design. The research sample consisted of sixty students in 7th grade. Thirty students in the sample were in the experimental group, thirty students were in the control group and the experimental and control groups were randomly assigned. Liquid Pressure Conceptual Understanding Test (LPCUT) was used to determine the students' ideas about liquid pressure. Semi-structured interviews were conducted with nine students in the experimental group before and after the instruction. A rubric consisting of five categories was used in the analysis of LPCUT. According to the results of the study, it was determined that the students in the experimental group who received instruction based on open inquiry gave a higher rate of scientific answers than the students in the control group. Based on the results of the research, it is thought that the use of the instructions revealed in the OIBL environment in science courses may be beneficial for the academic achievement of the students. Moreover, an increase was observed in the scientific response rates of the students in the group taught according to the science program. In the light of the results obtained from this study, it can be suggested to investigate the effects of OIBL on students' ideas in different concepts.

Keywords:

Open inquiry based learning, conceptual understanding, liquid pressure, secondary school students

Introduction

There has been a lot of debate about how learning takes place globally in the last century. As an alternative to traditional learning methods, new student-centered learning methods are adopted to build new skills based on problem solving, information literacy and collaboration (AAAS, 1993). Among these methods,

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inquiry based learning is defined as a question-oriented approach that involves conducting scientific research, interpreting data, and discussing findings (Wu & Hsieh, 2006). Inquiry based learning approach is an approach that encourages teachers to enable students to discover and solve real-life problems (Li & Lim, 2008). Inquiry based learning approach asks students to solve the problems they face in daily life by following the scientific research process (NRC, 2000). Students take an active role in the inquiry process and are active at every stage of the process.

The most complex type of inquiry, open inquiry, starts with the student's own question and designs the process itself (Adler, Zion & Rimerman-Shmueli, 2019). The teacher does not intervene in the student-led inquiry process and the process is carried out by the students. The open inquiry based learning (OIBL) approach which is thought to be such an effective method on students' learning processes and skills is given below. In an open inquiry, the teacher defines the information frame in which the inquiry is made, but leaves the students to choose the questions they wonder. In this process, students investigate the questions chosen by them (Sotáková, Ganajová & Babinčáková, 2020). Students manage the learning process by taking responsibility at every stage of the open inquiry process (Zion & Mendelovici, 2012). Sadeh and Zion (2009) see the participation of the student as the key to open inquiry in the investigating of the questions. In open inquiry, students take more responsibility and have the opportunity to collaborate more in the working groups by being more involved in the learning process (Sadeh & Zion, 2012). At the same time, it encourages students to reason scientifically and follow activities to reflect on the inquiry process (Baur & Emden, 2021). The role of the teacher is to leave learning to the will of the student and to provide a complete environment for the students to do their own activities (Dober, et al, 2017; Van der Valk & de Jong, 2009). According to Chin and Chia (2004), open inquiry requires high-level thinking, and an important element in performing such an inquiry is the ability of teachers to motivate their students to ask questions that guide them in their inquiry. In open inquiry, students express the problem, formulate the hypothesis, and develop their own study designs. While open inquiry focuses on the research process, its content depends on the direction in which the student chooses to research (Zion, Cohen & Amir, 2007). Open inquiry is the highest level of inquiry based learning and it is complex. Studies show that OIBL approach is effective on students' conceptual understanding of various concepts (Acar & Tuncdogan, 2019; Cairns, 2019; Engudar, Bostan-Sarioğlan & Dolu, 2020; Yang & Park, 2017).

It is supported by the studies that the use of open inquiry method is effective in solving the problem faced by students in learning process (Roth, 1999). In addition, it is stated that open inquiry method is effective in improving students' inquiry skills (Berg, Bergendahl, Lundberg & Tibell, 2003; Zion & Mendelovici, 2012). Inquiry based learning approach improves students' inquiry skills and thus it is thought that will help to solve problems in daily life. The use of open inquiry method was preferred in this study because it had an effect on students' conceptual understanding. In addition, this study is expected to provide information about whether OIBL approach is appropriate to the level of students at this age. Liquid pressure is also an important part of students' daily life experiences. Liquid pressure is one of the top subjects that students have difficulty in learning among science subjects at secondary school level. In particular, it is revealed that the students have difficulties in learning the pressure-force relationship (Besson, 2004; Goszewski et al., 2013; Kaya, Bozdağ & Ok, 2018; Moyer, Bazan & Wagner, 2013; Saputra, Setiawan & Rusdiana 2019). The results of these studies show that students have difficulty understanding the concept of liquid pressure. For this reason, it is thought that more studies should be done to teach concept of liquid pressure. Studies in which various teaching methods are used for the teaching of concept of liquid pressure are carried out. For example; the effects of teaching techniques such as 5E learning model (Sahin, Calık & Cepni, 2009), reciprocal peer instruction (Alemu, 2020), use of computer supported conceptual change texts (Şahin, İpek & Çepni, 2010), STEM approach (Chasanah, Kaniawati & Hernan, 2017; Ozdemir, 2021; Özcan & Koca, 2019), use of computer simulation (Yian et. al, 2012) on students' ideas about concept of liquid pressure were investigated. As mentioned above, while the studies aiming to determine the opinions of the students about concept of liquid pressure were included in the literature, there were no studies investigating the effects of the inquiry based learning method based on the students' ideas about this concept. Moreover, studies show that OIBL approach is effective on students' ideas related to various concepts. For these reasons, in this study, it is thought that OIBL approach will make a different contribution to fate in terms of investigating the effect of secondary school students on conceptual understanding of liquid pressure. It is thought that the use of an OIBL approach in teaching the concept of liquid pressure will present a different perspective to the field in this respect. In this study, it is aimed to investigate the effect of OIBL approach on the conceptual understanding of liquid pressure concept of secondary school students. Based on this situation, the research questions are listed below.

Research Questions

The research questions aimed to be answered in this study are as follows;

- What are the effects of the OIBL approach on secondary school 7th grade students' conceptual understanding regarding the concept of liquid pressure?
- What are the effects of instruction according to the science curriculum on secondary school 7th grade students' conceptual understanding regarding the concept of liquid pressure?

Method

The research design, sample, data collection tools, data analysis process and instruction steps are explained in this section.

Research Design

In this study, a quasi-experimental research design with pre-test and post-test control groups was used. In experimental research, researchers apply comparable procedures and then examine the effects of these procedures. In pre-test and post-test studies with unequalled control group design, groups are assigned to experimental and control groups by random assignment (Cohen, Manion & Morrison, 2007). In this study, experimental and control groups were determined randomly. The research design is given in Table 1 below.

Table 1. Research design of the study

	Pre-test Before Instruction (BI)	**Procedure**	**Post-test After Instruction (AI)**
Experimental Group Students (EGS)	T_1, T_2	X_1	T_1, T_2
Control Group Students (CGS)	T_1	X_2	T_1

T_1: Liquid Pressure Conceptual Understanding Test (LPCUT); *T_2*: Semi-structured Interview;
X_1: Open Inquiry Based Learning (OIBL); *X_2*: Instruction According to Science Program

Sampling

The sample of the study consists of 60 students of 7th class that studies in two different classrooms in a state secondary school in the western part of Turkey. OIBL instruction was given to the students in the experimental group (N = 30), and education that is suitable to the science program was given to the students in the control group (N = 30). 45% of the students in the study are female and 55% are male participants. At the same time, 16 of the 30 students in the experimental group were male and 14 were female. In the control group, there were a total of 30 students, 13 girls and 17 boys. For the students to work together in the open inquiry process, the experimental group was divided into six study groups consisting of five people.

Data Collection Tools

In this research, two data collection tools were used to collect data from students. These tools were the Liquid Pressure Conceptual Understanding Test (LPCUT) and semi-structured interviews with the students in the experimental group before instruction (BI) and after instruction (AI) to support the data obtained from LPCUT.

Liquid Pressure Conceptual Understanding Test (LPCUT)

LPCUT was developed to determine students' ideas about liquid pressure. LPCUT, which was first prepared in four questions, was consulted by two expert lecturers who were experts in their field in determining the content validity. After receiving expert opinions, some adjustments were made to the questions. A pilot study was conducted to determine the reliability of the questions in the LPCUT. The pilot study of LPCUT was applied to 105 8th grade students who studied these concepts in previous years. After the pilot study, the points that the students had difficulties in understanding were determined, and one question was removed from the test. In another question, it was determined that the visuals were not understood by the students and replaced with new ones. As a result, LPCUT was created with three open ended questions. For the validity of LPCUT, it was submitted to two science education experts and the test was finalized. The LPCUT includes three open-ended questions to determine students' views on liquid pressure.

Semi-Structured Interview

The semi-structured interview aimed to reveal the students' views on the concept of liquid pressure in more detail. Semi-structured interview questions were prepared by the researcher in order to get the opinions of the students. For the validity of the interview questions, expert opinions were taken from two experts on science education and some questions were rearranged in line with the suggestions made. The interviews were conducted with nine volunteer students from the experimental group BI and AI. The students interviewed were determined according to their success in the general science lesson, and three students were selected from among the successful students, three students were selected from among the students with middle achievement and the other three students were low successful students. The questions asked in the interview aim to determine in more detail the reasons for their answers to the LPCUT questions. The interview questions were parallel to the questions in the open-ended conceptual comprehension test and attention was paid to reveal situations that the open-ended questions could not question. Permission was taken from the interviewed students and volunteering was taken as basis. The interviews were recorded with voice recorder.

Data Analysis

This chapter deals with the analysis of the data obtained from the data collection tools introduced in the previous sections.

In the analysis of LPCUT, the answers of the students were examined one by one. According to the answers obtained from the students, the answer categories to be used for the analysis were determined in the direction of the students' answers during the analysis process. The types of provided answers were grouped under the title of "scientifically accepted answers" as “fully correct” and “partially correct; and "scientifically unaccepted answers" as "non-codable" and "no answer". Firstly, the correct answer to the question was determined. Then, the answers of the students were examined one by one and the test numbers of the students who gave the correct answer were written under the “fully correct" category. The answers that are correct from the students' answers but which contain less direct explanations in one aspect are grouped under the so-called “partially correct" category. The answers in this category do not contain incorrect answers. In this way, scientifically acceptable answers are grouped. Scientifically unacceptable answers consist of students' false, alternative conceptual and incorrect answers. The non-codable category consists of the answers that the students give without any connection with the subject. In the "no answer" category, students who did not respond were grouped. In order to ensure reliability in the analysis of data obtained from open-ended questions, independent data analysis was conducted by two researchers. Both researchers analyzed the answers of the students independently and placed them into categories. As a result of the analysis, the reliability percentage of the researchers was calculated as 88% according to Miles and Huberman (1994).

During the interviews, the answers given by the students to the open-ended questions were examined and it was tried to obtain more clear information about the reasons of the answers. Nine students from the experimental group were interviewed BI and AI based on open inquiry. The data obtained from the interview were converted into written format by the researchers. When converting to the written format, first the interview code and then the number given to the student were used instead of the names of the students. For example, if the interview was done BI process with the seventh student, this was coded as BIS7 (Before Instruction Student 7); or if the interview was AI with the fifth student, this was coded as AIS5 (After Instruction Student 5). Since all the students interviewed were in the experimental group, no coding was made indicating that they were in the experimental group.

Findings

In this section, the findings of the students' responses to LPCUT and semi-structured interviews are given.

The first question of LPCUT was asked to question why the dam walls were made thicker at depths. In this question, students are expected to realize that when the depth of the liquid increases, the pressure of the liquid should increase. The findings obtained from the analysis of this question are given in Table 2.

Table 2. Students' response types to the first question of LPCUT

LPCUT 1st QUESTION	**EGS**		**CGS**	
RESPONSE TYPES	**BI**	**AI**	**BI**	**AI**
	n *(%)*	n *(%)*	n *(%)*	n *(%)*
A. SCIENTIFICALLY ACCEPTED ANSWERS				
1.Fully Correct	6 (*20*)	21 (*70*)	12 (*40*)	19 (*63.3*)
2.Partially Correct	3 (*10*)	1 (*3.3*)	8 (*26.7*)	6 (*20*)
Total	**9 (*30*)**	**22 (*73.3*)**	**20 (*66.7*)**	**25 (*83.3*)**
B. SCIENTIFICALLY UNACCEPTED ANSWERS				
The water force is higher at the bottom	5 (*16.7*)	0 (*0*)	0 (*0*)	0 (*0*)
Because the water melts the soil	1 (*3.3*)	0 (*0*)	0 (*0*)	0 (*0*)
Because there is a lot of water under the dam	6 (*20*)	0 (*0*)	2 (*6.7*)	0 (*0*)
Water under the dams becomes stronger	1 (*3.3*)	1 (*3.3*)	0 (*0*)	0 (*0*)
The water density increases at the bottom	3 (*10*)	3 (*10*)	0 (*0*)	0 (*0*)
So that the dam does not overflow	0 (*0*)	0 (*0*)	2 (*6.7*)	0 (*0*)
Total	**16 (*53.3*)**	**4 (*13.3*)**	**4 (*13.3*)**	**0 (*0*)**
C. NON-CODABLE	3 (*10*)	3 (*10*)	6 (*20*)	4 (*13.3*)
D. NO ANSWER	2 (*6.7*)	1 (*3.3*)	0 (*0*)	0 (*0*)
Total	**30 (*100*)**	**30 (*100*)**	**30 (*100*)**	**30 (*100*)**

It was observed that the percentages of the EGS who answered correctly in scientifically accepted answers increased from 20% in the pre-test to 70% in the post-test, and the percentages of the CGS increased from 40% in the pre-test to 63.3% in the post-test. It was observed that the percentages of the EGS who responded partially in the correct answer category decreased from 10% in the pre-test to 3.3% in the post-test, while this rate decreased from 26.7% in the pre-test to 20% in the post-test.

The following statements were obtained from the semi-structured observations made with the students who gave non-scientific answers BI in the experimental group and gave the scientific answers AI:

Before instruction;

R: "Why are the dam walls thicker? Can you explain?"

BIS6: " Because, the water force is higher at the bottom."

R: "What do you mean by water force? What causes that force? And how come this force increases at the bottom?"

BIS6: " It is the increase in the density of the water at the depth that causes the increase of the force."

Another student answered the interviewer as follows.

R: "Why are dam walls thicker in the depths of water? Can you explain?"

BIS30: "Because the water is more severe on the bottom."

R: "What causes the water force to increase in the bottom? Why do you think like this?"

BIS30: "Because there's more weight on the bottom."

The sections of the interviews with the students AI are as follows;

AIS6: "Because if the depth increases, the liquid pressure increases."

R: "Initially, you didn't think like that. What changed your mind?"

AIS6: "Actually, at the beginning, I meant to say that there is more water on the surfaces in the depths. But I used the concept of density. In our U-pipe experiments, I found that the liquid pressure was directly proportional to the depth and density."

Another student's answer AI to the same question is as follows.

AIS30: "Because the liquid pressure increases if the depth increases. In the U-pipe test, when we pushed the end of the funnel down in graduated cylinder, we found that the liquid pressure increased."

In the category of scientifically unacceptable answers, six different alternative concepts written by the students have been identified for the 1st question of LPCUT. While the percentage of the experimental group responding as "Because there is a lot of water under the dam" was 20% BI, no students were encountered AI, while the percentage of the students who gave this answer in the pre-test was 6.7%, it was observed that no student gave this answer in the final test. While the percentage of the EGS who answered "The water force is higher at the bottom" was 16.7% in the pre-test, it was observed that none of the students gave this answer in the post-test, and none of the students in the pre-test and post-test gave this answer in the post-test. It was observed that "The water density increases at the bottom" answer was given by 10% of the EGS in the pre-test and post-test, and no students gave this answer in the pre-test and post-test in the CGS. While the percentage of the EGS who answered "Because the water melts the soil" was 3.3% BI, it was observed that none of the students gave this answer AI, and none of the students in the control group gave this answer in the pre-test and post-test. The percentage of the EGS who answered "Water under the dams becomes stronger" was 3.3% BI and AI, meanwhile it was observed that no students gave this answer in the pre-test and post-test in the CGS. In the pre-test and post-test, no answer was given by "So that the dam does not overflow" in the experimental group, while the percentage of the students who gave this answer in the pre-test was 6.7%, it was observed that none of the students gave this answer in the post-test. It was observed that the percentages of the EGS whose answers couldn't be codded, BI and AI, were 10%, and the CGS decreased from 20% in the pre-test to 13.3% in the post-test. It was observed that the percentage of the EGS who left the question unanswered decreased from 6.7% BI to 3.3% AI and in control group, although there was no one who left the question unanswered in the pre-test, this ratio was observed to be 3.3% in the post-test.

The second question of LPCUT was asked by drawing as: "What can we say about the flushing distances of the liquids in the containers when we put equal volume of liquid in two identical containers and drill a hole at the same depth? Explain the reason for your answer". In this question, students are expected to realize that the liquid pressure is directly proportional to the density of the liquid.

Table 3. Students' response types to the second question of LPCUT

LPCUT 2nd QUESTION	**EGS**		**CGS**	
RESPONSE TYPES	**BI** n *(%)*	**AI** n *(%)*	**BI** n *(%)*	**AI** n *(%)*
A. SCIENTIFICALLY ACCEPTED ANSWERS				
1. Fully Correct	1 (*3.3*)	20 (*66.7*)	2 (*6.7*)	11(*36.7*)
2.Partially Correct	11 (*36.7*)	3 (*10*)	10(*33.3*)	2 (*6.7*)
Total	**12 (*40*)**	**23 (*76.7*)**	**12 (*40*)**	**13(*43.3*)**
B. SCIENTIFICALLY UNACCEPTED ANSWERS				
Liquid with lower density gushes farther	5 (*16.7*)	5 (*16.7*)	3 (*10*)	0 (*0*)
The spirits gush farther. Because it is acidic	1 (*3.3*)	0 (*0*)	0 (*0*)	0 (*0*)
The flushing distances are the same	1 (*3.3*)	0 (*0*)	0 (*0*)	0 (*0*)
Liquid with a higher density gushes farther Because it is less liquid	0 (*0*)	0 (*0*)	1 (*3.3*)	2 (*6.7*)
Since water is more liquid, it gushes farther	0 (*0*)	0 (*0*)	1 (*3.3*)	3 (*10*)
Water gushes farther. Because volume of water is	0 (*0*)	0 (*0*)	0 (*0*)	2 (*6.7*)
Since it is burnable, spirit gushes farther	0 (*0*)	0 (*0*)	0 (*0*)	1 (*3.3*)
Both gush out equal distance	0 (*0*)	0 (*0*)	0 (*0*)	1 (*3.3*)
Total	**7 (23.3)**	**5 (*16.7*)**	**5 (*16.7*)**	**9 (*30*)**
C. NON-CODABLE	9 (*30*)	1 (*3.3*)	9 (*30*)	4 (*13.3*)
D. NO ANSWER	2 (*6.7*)	1 (*3.3*)	4 (*13.3*)	4 (*13.3*)
Total	**30 (*100*)**	**30 (*100*)**	**30 (*100*)**	**30 (*100*)**

In this question, it was observed that the percentages of EGS who answered correctly in scientifically acceptable answers increased from 3.3% in the pre-test to 66.7% in the post-test, while the percentage of CGS increased from 6.7% in the pre-test to 36.7% in the post-test. It was observed that the percentages of the EGS who gave answers in the partially correct answer category decreased from 36.7% in the pre-test to 10% in the post-test, while this ratio decreased from 33.3% in the pre-test to 6.7% in the post-test.

When examining the scientifically unacceptable answers for the second question of LPCUT, eight different alternative concepts written by the students were encountered. While the percentage of the EGS who answered "Liquid with lower density gushes farther" was 16.7% in the pre-test and post-test, it was observed that 10% of the CGS did not give any answer AI. It was observed that the percentage of EGS who answered as "Spirits gush farther. Because it is acidic" which is an alternative concept encountered in students, was 3.3% BI; it was observed that none of the students gave this answer AI, and none of the students in the control group gave this answer in the pre-test and post-test. While the percentage of the EGS who answered "The flushing distances are the same. Because it depends only on depth" was 3.3% BI, it was observed that no student gave this answer AI, and none of the CGS gave this answer in the pre-test and post-test. It was observed that no student gave the answer "Liquid with a higher density gushes farther. Because it is less liquid" BI and AI and the percentage of students who gave this answer BI the instruction increased from 3.3% to 6.7% AI. It was observed that no student gave the answer BI and AI of "since water is more liquid, it gushes farther" and the percentage of the students who gave this answer BI increased from 3.3% to 10% AI. The answer "Water gushes farther. Because volume of water is greater" was not observed by any student in the experimental group BI and AI, whereas in the CGS there were no students who gave this answer BI, the percentage of those who responded in this way AI was observed as 6.7%. It was observed that BI and AI, no students gave the answer "Since it is burnable, spirit gushes farther" in the experimental group and none of the students in the control group gave this answer BI, the percentage of those who responded in this way AI was observed as 3.3%. It was observed that "Both gush out equal distance" was not given by any student in the experimental group BI and AI. In the CGS, no students who gave this answer were observed BI, while the percentage of those who responded in this way AI was observed as 3.3%. It was observed that the percentage of students in the experimental group whose answers could not be coded decreased from 30% BI to 3.3% AI, while the CGS decreased from 30% BI to 13.3% AI. The percentage of EGS who did not answer this question decreased from 6.7% BI to 3.3% AI, while the percentage of control group was observed to be 13.3% BI and AI.

The 3rd question of LPCUT is prepared by drawing a bottle shape as "this bottle was drilled from top to bottom with three holes and these holes were covered with playing tape. When we remove the tapes from the holes, which hole in the water gushes forward? Explain the reason for your answer". In this question, students are expected to realize that the liquid pressure is directly proportional to the depth of the liquid.

Table 4. Students' response types to the third question of LPCUT

LPCUT 3rd QUESTION	**EGS**		**CGS**	
RESPONSE TYPES	**BI** n *(%)*	**AI** n *(%)*	**BI** n *(%)*	**AI** n *(%)*
A. SCIENTIFICALLY ACCEPTED ANSWERS				
1.Fully Correct	2 (*6.7)*	12 (*40)*	4 *(13.3)*	*53.3* (16)
2.Partially Correct	11 (*36.7)*	4 (*13.3)*	11 (*36.7)*	6 *(20)*
Total	**13 (*43.3)***	**16 (*53.3)***	**15 (*50)***	**22 (*73.3)***
B. SCIENTIFICALLY UNACCEPTED ANSWERS				
Water is stronger at the bottom	1 (*3.3)*	0 (*0)*	0 (*0)*	0 (*0)*
As water is drawn down by gravity, it gushes farther from the bottom	1 (*3.3)*	0 (*0)*	0 (*0)*	0 (*0)*
Water makes more pressure on the upper part of the bottle	2 (*6.7)*	0 (*0)*	0 (*0)*	0 (*0)*
Since the amount of water at the bottom is higher, it gushes away	1 (*3.3)*	0 (*0)*	0 (*0)*	0 (*0)*
It gushes farther from the middle hole. Because it is influenced by both sides	2 (*6.7)*	0 (*0)*	0 (*0)*	0 (*0)*
The liquid density is higher in the depths. Therefore, the pressure at the bottom is excessive	2 (*6.7)*	8 (*26.7)*	1 (*3.3)*	1 (*3.3)*
Water flows from top to bottom. So the pressure is higher at the bottom	0 (*0)*	0 (*0)*	1 (*3.3)*	0 (*0)*
Liquid pressure is applied only at the bottom	0 (*0)*	0 (*0)*	2 (*6.6)*	0 (*0)*
Total	**9 (*30)***	**8 (*26.7)***	**4 (*13.3)***	**1 (*3.3)***

C. NON-CODABLE		8 (*26.7*)	4 (*13.3*)	10 (*33.3*)	6 (*20*)
D. NO ANSWER		0 (*0*)	2 (*6.7*)	1 (*3.3*)	1 (*3.3*)
	Total	**30 (*100*)**	**30 (*100*)**	**30 (*100*)**	**30 (*100*)**

In the third question, it was observed that the percentages of EGS who gave the correct answer in scientifically accepted answers increased from 6.7% BI to 40% AI, and the percentage of CGS increased from 13.3% BI to 53.3% AI. It was observed that the percentages of the EGS who responded as partially correct answers decreased from 36.7% BI to 13.3% AI, and this rate decreased from 36.7% BI to 20% AI. In semi-structured interviews with students, in questions the relationship between the liquid pressure and the depth of the liquid was questioned. The following statements were obtained during the interviews;

R: "When we drill holes from top to bottom into a container filled with liquid, from which hole does the liquid gush out farther? Can you explain why?"

Before instruction;

BIS5: "From the hole at the bottom, because the liquid density at the bottom is higher."

After instruction;

AIS5: "The liquid gushes further away from the bottom hole. Because liquid pressure depends on the depth and density of the liquid. There's the same liquid in the container, so the density is constant. But at the bottom, the depth is higher, so the pressure is higher."

R: "Your initial opinion has changed. What makes you change your mind?"

AIS5: "In our classroom, the group next to us did the same experiment. We noticed it both in their experiment and in our experiment."

When examining the scientifically unaccepted answers for the 3rd question of, nine different alternative concepts written by the students were encountered. While the percentage of the students who gave "Water is stronger at the bottom." answer in the experimental group was 3.3% BI, it was observed that none of the students gave this answer in the post test, and none of the students in the control group gave this answer BI and AI. While the percentage of the EGS who answered "As water is drawn down by gravity, it gushes farther from the bottom" was 3.3% BI, it was observed that no students gave this answer AI, and none of the CGS gave this answer BI and AI. It was observed that while the percentage of the EGS who answered "Water makes more pressure on the upper part of the bottle" was 6.7% BI, no students gave this answer AI, and none of the CGS "Since the amount of water at the bottom is higher, it gushes away" was 3.3% BI, no students gave this answer AI, and none of the students in the control group gave this answer BI and AI. It was observed that the percentage of the EGS who answered "It gushes farther from the middle hole. Because it is influenced by both sides" was 6.7% BI and no students gave this answer AI, and none of the CGS responded as "The liquid density is higher in the depths. Therefore, the pressure at the bottom is excessive" increased from 6.7% BI to 26.7% AI. It was observed that "Water flows from top to bottom. So the pressure is higher at the bottom" in the experimental group BI and AI, while the percentage of the CGS was 3.3% BI, no students gave this answer AI. It was observed that "Liquid pressure is applied only at the bottom" answers were given by no students in the experimental group BI and AI, while the percentage of the students in the control group was 6.6% BI, no students gave this answer AI. It was observed that the percentage of the EGS who answered the question in the non-codable category decreased from 30% BI to 26.7% AI, while the CGS decreased from 13.3% BI to 3.3% AI. In this question, none of the students in the experimental group left this question unanswered BI, while 6.7% of the students left unanswered AI. The percentage of students in the control group who did not answer the question was observed as 3.3% BI and AI.

Conclusion and Discussion

In this study, the conceptual understanding of the liquid pressure concept of the students in the experimental group, whom were taught by using the OIBL approach and in the control group, whom were taught by using the science education program was determined, and the effects of these two teaching methods on the students' conceptual understandings were compared. According to the results obtained from first question, the scientific response rate of the students in the experimental group before instruction was much lower than the students in the control group. There was an increase in the scientific response rate of the students in the experimental group where open inquiry was used. Also, there was an increase in the scientific response rate of the CGS after instruction. The increase in the experimental group was higher than the control group. For second question, while the rate of scientifically correct answers of the students in the experimental group and the control group was equal before instruction, the rate of scientific response of the students in the experimental group was higher after instruction based on open inquiry. The OIBL approach in the experimental group and the instruction in accordance with the science program in the control group seem to have an impact on the students' conceptual understanding in these questions. In both teaching methods, students' scientific response rates increased and alternative concepts decreased for these questions. In these questions, it is seen that OIBL approach causes more increase in scientific answers about concept of liquid pressure. Balım (2009) has come across the result that inquiry based learning approach is effective in secondary school students' understanding of the concept of liquid pressure. So, we can say that the OIBL approach has been more effective in students' conceptual understanding. Similar to this result, in the studies of Khalaf and Zin (2018) and Minner, Levy, and Century (2010) stated that inquiry based learning has a significant effect on students' conceptual understanding compared to other teaching methods. Similarly, Abdi (2014) came across the result that inquiry based learning approach is more effective than traditional teaching on the ideas of secondary school students. In the experimental group, the OIBL approach was effective in the alternative concepts where the lower sides of the dams were thicker, since there was more water force under the dams and there was more water under the dams and these alternative concepts were not encountered after instruction process. Besson (2004) encountered a similar understanding of the idea that there would be more water in the lower parts of the dams in his study with students and teachers. In this study, while this alternative concept was encountered before instruction, the conceptual understanding of the students changed after instruction. In second question, instruction based on open inquiry led to a decrease in the alternative concepts encountered in the students, whereas the instruction in accordance with the science program caused an increase in the alternative concepts of the students. Instruction may cause students to form alternative concepts other than scientific knowledge (Chinn & Brewer, 1993; Suprapto, 2020). In this question, the courses taught in accordance with the program caused the students to develop alternative concepts. Based on this result, it can be said that the use of different learning approaches in instruction the same concept affects students' conceptual understanding in a different direction. Similarly, Wise (1996) analysed different learning approaches and concluded that the effects of these methods on student achievement were different. In third question, the rate of scientific response of the students in the experimental and control groups increased after instruction, but this increase was higher in the students in the control group. It is seen that the instruction performed in the control group is more effective than the instruction in the experimental group in providing scientific answers for this question. After instruction, the students in the control group gave a higher rate of scientific answers than the students in the experimental group. When we look at the answers of the students in the experimental and control groups, the ratio of encountering alternative concepts after instruction decreased in both groups, but the ratio of encountering alternative concepts in the control group was less. In the experimental group, the alternative concept of "pressure is lower at the bottom because of the density of liquid in the depths" was encountered in two students before instruction, and this number was increased in eight students after instruction. Similarly, Karaman (2011) states that secondary school students have alternative conceptions in relating liquid pressure with the density of the liquid, and that teaching is not effective in completely eliminating these alternative conceptions. Goszewski et al. (2013) and Wijaya and Muhardjito (2016) encountered similar alternative concepts in their studies. In addition, as a result of this study, an alternative conception was encountered that the liquid pressure depends on the amount of liquid. Similarly, Karaman (2011) and Ozdemir (2021) encountered this misconception in middle school students as a result of their studies. It is seen that instruction based on open inquiry causes students to form ideas about this alternative concept. This result coincides with the conclusion that in some cases Strike and Posner (1992) stated that alternative concepts may emerge after instruction. A similar result has been reported in previous studies showing that some alternative concepts persist despite formal instruction (Bostan-Sarıoğlan & Küçüközer, 2015; Hsu, 2008).

If we look at the results obtained from LPCUT in general, the OIBL in the experimental group and the science program instruction in the control group led to an increase in the scientific response rate of the students in both groups. In the studies, it was similarly found that inquiry based instruction was effective on students' conceptual understanding (Anderson, 2002; Rahmat & Chanunan, 2018; Şimşek & Kabapınar, 2010; Ucar & Trundle, 2011). In this study, the scientific response rates of the students in both groups increased AI and this is a desired result. In the first and second questions of LPCUT, while the scientific response rate of the EGS increased more after instruction, it was observed that although the scientific response rate of the students in both groups increased in the third question, the increase was higher in the control group. In general, OIBL instruction has led to an increase in students' scientific responses, while also affecting their conceptual understanding of alternative concepts. It has been found in the studies that students who have inquiry based learning have higher academic achievement compared to students using other teaching methods (Chang & Mao, 1999; Jiun, Kamarudin, Talib & Hassan, 2018; Tezel, Semiz & Uçar, 2020). Unlike this result, Liou (2021) revealed that inquiry based learning practices had a significant negative effect on students' science achievement, whereas teacher directed instruction had a significant positive effect on students' science achievement. Nevertheless, as a result of many studies, it is stated that inquiry-based learning is effective on students' science achievement. Based on the results of the study, it is thought that the use of OIBL instruction is effective in the conceptual understanding of secondary school students and therefore it would be appropriate to use it in students in this age group. Based on these results, the recommendations given below have been made.

Recommendations to Future Studies

It has been supported by studies that open inquiry has a positive effect on students' high level inquiry skills and affective factors. Further studies can be conducted in this area to investigate the effects of students on conceptual change and conceptual durability. In the results of this study, it is seen that open inquiry is not sufficient to change the students' conceptual understanding of some alternative concepts or in some cases it causes conceptual understanding of new alternative concepts. Studies on the effects of open inquiry on conceptual change should be investigated in more detail. Perhaps studies that compare and discuss the effects of open inquiry and guided inquiry on students' ideas can be conducted. Open inquiry also requires some competencies for teachers and difficulties are experienced by teachers in its implementation in this respect. In particular, studies can be conducted with teachers on how to support students in this process. One of the suggestions of this study is to carry out more studies about teaching liquid pressure concept to different age students by using different learning methods.

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