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8th Grade Students' Opinions on 3D Virtual Laboratory Applications

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Abstract: Experimental applications in science education make learning more meaningful, and learning without experimenting cannot be fully absorbed. However, increasing costs, time constraints and risk factors that may occur during the application make hand-made experiment activities difficult. The aim of this study is to examine the effect of the 3D virtual laboratory application prepared for science education on students, unlike traditional plain lecture teaching, and to reveal the opinions of students who are taught with the application. In this context, the research was conducted on 5 8th grade students in Konya province in the 2021-2022 academic year with the 3D virtual laboratory application prepared for the science unit "Matter and Industry". After the research, a semi-structured interview was conducted in which open-ended questions were asked to the students about the applications and the process, and the students' verbal opinions were taken. During the interview, student conversations were recorded on the computer and then transcribed and examined. As a result of the interviews with the students, it was seen that the effects of 3D virtual laboratory applications on students were very positive. In addition, considering cost, time and risk factors, it can be suggested that virtual laboratory applications may be preferred to handmade activities.

Keywords: Educational technology, Virtual laboratory, 3D virtual laboratory, Science education

Introduction

Science course is one of the most important branches of science that facilitates individuals to understand themselves, the events around them and the world (Kiray, 2011). In this regard, Sözbilir et al. (2015) say that science education supports the development and progress of societies, as well as having an important place in raising individuals with the knowledge, skills, attitudes and behaviors required by the age, and in making sense of the world they live in. Çoban (2009) listed the main purpose of science education as providing students with science concepts and scientific process skills, and its sub-purposes as; following technological innovations, providing cognitive development, being ready for the next level of education, getting to know nature and daily life, developing a positive attitude towards science, explaining current events with scientific facts, etc.

There are both concrete subjects that can be encountered in daily life and abstract subjects that students may have difficulty understanding in science courses. Laboratory activities are very important for these abstract concepts to be learned meaningfully (Köseoğlu & Bayır, 2012). Using laboratory methods is an effective method to make science subjects concrete. (Aydoğdu & Şener, 2016; Boesdorfer & Livermore, 2018; Chopra et al., 2017; Kılıç et al., 2015; Lawson, 2002). Laboratory activities provide students with effective experiences in scientific studies in order to gain skills such as defining the problem, making observations, classifying, collecting data, conducting experiments and analyzing the results (Aydoğdu & Kesercioğlu, 2005).

There are multiple obstacles encountered during teaching students with handmade activities in a laboratory environment. These obstacles can be listed as; handmade activities in crowded classes being teacher-centered, physical inadequacies in laboratories, costs of equipment, laboratory studies not being made available to students, difficulty in classroom control in young age groups, difficulties in supplying materials, high costs of carrying out some activities, insufficient time for long-term experiments, inability to repeat experiments sufficiently, hazardous materials and safety problems (Akıllı & Aydoğdu, 2018; Altun et al., 2009; Aydoğdu & Şener, 2016; Bretz, 2019; Doiron, 2009; Kaba, 2012; Meral et al., 2014).

Virtual Laboratory

Due to these problems and the impact of technological developments, virtual laboratory applications have increased (İnce & Kutlu, 2014). Virtual laboratories are especially prominent in teaching applied courses (science, engineering, medicine, etc.) at high school and university levels (Yu et al., 2005). Learning methods carried out with computers allow students to learn the subject by repeating activities many times through trial and error. Thus, students are encouraged to find different solutions to the problems they encounter (Shute et al., 2017). In addition, students have the opportunity to perform activities whenever and wherever they want, to leave them unfinished and to complete them later (Bozkurt & Sarıkoç, 2008). Virtual applications are needed especially in abstract subjects that are difficult to understand and do, and in very costly and laborious technical experiments (Scherp, 2002).

Economic reasons are another important factor supporting the spread of virtual laboratory applications (Koç, 2019). Such applications are important for all educational institutions that do not have a laboratory or have inadequate physical facilities (materials, tools, machines, etc.). In addition to these inadequacies, activities in crowded classes in schools can only be carried out by teachers through demonstration methods. This increases the importance of virtual laboratory applications created with simulation software (Özdener, 2004).

Despite the advantages given above, virtual laboratory applications also have many limitations (Sari et al., 2019). In their research, Bucos et al. (2008) stated that idealized results, limited cooperation between students, and lack of physical interaction with laboratory equipment are the limitations of virtual laboratories. According to Wang and Lu (2003), virtual laboratories are only useful for some courses (science, engineering, etc.), but if adapted to other courses, they lose the desired flexibility.

In his study, Doiron (2009) defined the absence of a teacher in practice and lack of feedback in answers, other students' inability to hear their questions and the teacher's answer, deficiencies and problems encountered in computer use, and complex simulations as the prominent limitations of virtual laboratories. In addition, studies have shown that minimizing errors in computer simulations also brings with it the risk of students losing the ability and motivation to conduct physical research (Chen, 2010).

When the literature is examined, it is seen that virtual laboratories prepared with simulations have accepted advantages and disadvantages compared to plain narration. When the research groups in which these studies were conducted are examined, it is seen that the majority of the studies were carried out at high school or undergraduate level and only the effectiveness of the virtual laboratory was measured and no comparison was made with handmade activities. In addition, it is noticeable that interviews conducted with students are limited in studies (Altun et al., 2009; Geçikli & Akgül, 2018; Dyrberg et al., 2016; Eljack et al., 2020; Evstatiev et al., 2022; Heradio et al., 2016; Karagöz-Mırçık & Saka 2016; Kavlak & Birhanlı, 2023; Makransky et al., 2017; Mutlu, 2015; Özdemir, 2019: Potkonjak et al., 2016; Tatlı & Ayas, 2011; Ural, 2016).

Considering the small number of studies conducted at the secondary school level in the emergence of the problem situation of the study, it was aimed to investigate the effectiveness of the virtual laboratory at the secondary school level. In this study, in order to determine the effectiveness of the virtual laboratory on students, interviews were conducted with students and their opinions were obtained. However, these data were not reflected in the comparison of the problems encountered and the achievements obtained during the handmade activities. Therefore, only the opinions of the students who took part in the virtual laboratory studies were included in the study groups.

When the problems encountered for handmade activities are examined, it is thought that the middle school subjects with the highest cost and safety risks are "Acids and Bases" and "Interaction of Matter with Heat" in the "Matter and Industry" unit at the 8th grade level. For this reason, a virtual laboratory was created within the scope of the relevant subjects. In addition, it is thought that examining the effect of the use of virtual laboratories, especially on middle school students, will contribute to the limited studies conducted in this field.

Method

Face-to-face interviews were conducted to determine the opinions of students studying with the virtual laboratory regarding the application. In this study, action research, one of the qualitative research designs, was used. Action research is a self-reflective research type conducted to increase the rationality and accuracy of an approach applied to students in educational sciences (Kemmis, 2010). This research is also known as teacher research because "the teacher assumes the role of the researcher in the research process" (Köklü, 2001) and its purpose is to examine its use in education (Beyhan, 2013). Action research is one of the tools that employees (teachers, experts, etc.) in educational organizations can use to produce solutions to their own problems or to renew themselves. In-depth interviews and observation-based determinations constitute the data collection techniques. The sample was formed with 5 randomly selected from among 21 students who studied with the 8th grade virtual laboratory.

While creating the sample, students who wanted to try virtual laboratory applications with computers at school and do their homework with computers at home were selected. Within the scope of the study, after the study group was decided, the necessary permissions were obtained from the students, their parents and the governor's office in order to carry out the application. The interviews were conducted with a semi-structured interview technique. In semi-structured interviews, previously prepared questions can be flexibly edited according to individuals and conditions, and information can be collected with additional questions (Çepni, 2010). The interview form was prepared by the researcher using open-ended questions after the relevant literature review. The necessary corrections were made by obtaining the opinions of a science field expert and a language expert.

Semi-structured questions were asked to obtain the data, and the data were collected from the participants through face-to-face interviews within the scope of the research. The written documents collected within the scope of the research were first transferred to the computer and analyzed using the content analysis method. Content analysis includes coding in the literature, grouping the codes selected from the statements of the participants or the researcher, and the concepts used in the social or human sciences under themes (Creswell & Plano Clark, 2020). The data of the research were categorized using the determined codes. It was aimed to reach a meaningful whole through this coding and categorization (Yıldırım & Şimşek, 2021). Finally, the definitions and interpretations of the findings were carried out. The participants were coded as "S1, S2, S3, S4 and S5" respectively (Table 1).

Table 1. Participants

Participant	Gender	Age
S1	Male	13
S2	Male	13
S3	Female	13
S4	Female	13
S5	Male	12

Validity and Reliability of the Study

Threats to the internal validity of the research are known as the characteristics of the participants in the experiments, the status of missing subjects, the laboratories where the application is made, the data collection process, the effect of the preliminary lesson on the research, undesirable situations that develop during the research process, maturation and the prejudices of the participants in the research (Fraenkel et al, 2018). These factors that threaten the internal validity of the study were taken into consideration by the researcher and the research process was carefully planned. Information on how the researcher tried to reduce the factors that threaten the internal validity of the study is given below.

In order to cope with the factor known as subject characteristics that threatens internal validity, students were divided into groups and made to play laboratory activities and games with their own classmates. The fact that the people who collected the data of the study were different is another factor that threatens internal validity for the study (Creswell, 2020). In this study, students were made to do handmade activities in the laboratory and play virtual games on computers, and the interview at the end of the process was carried out by the researcher himself. It can be said that these factors that threaten internal validity were partially eliminated by the researcher.

Another factor that poses a threat to internal validity in the study is the bias of the data collector (Fraenkel et al., 2018). For this reason, the researcher responded equally to the questions asked by the students during both the applications and the interviews. Care was taken to ensure that the researcher's attitude towards the students was at a similar level. This threat was also partially eliminated by the researcher.

The effect of the pre-lesson in research is also a factor that threatens internal validity (Patton, 2014). In order to eliminate this effect, the application periods of the games were not kept too short, so as not to give the students the opportunity to remember the pre-lesson, and this period was not kept too long, so that the maturation of the students could be an undesirable variable affecting the research, and it was limited to a total of 9 weeks. Maturation is also a factor that threatens internal validity for research. The researcher tried to reduce and partially eliminate the factors that threaten internal validity by immediately applying the interview at the end of the research.

The external validity of the research is the factor related to the generalization of the results obtained in the scales (Onwuegbuzie, 2018). The results of this study can be generalized to larger samples if similar conditions and environment are obtained during the research. For this reason, the results can be generalized with similar studies that meet the conditions of the research (Fraenkel et al., 2018).

Process

The work process was carried out in three stages: pre-implementation, implementation process, and post-implementation. The workflow for these processes is summarized in the visual below (Figure 1).

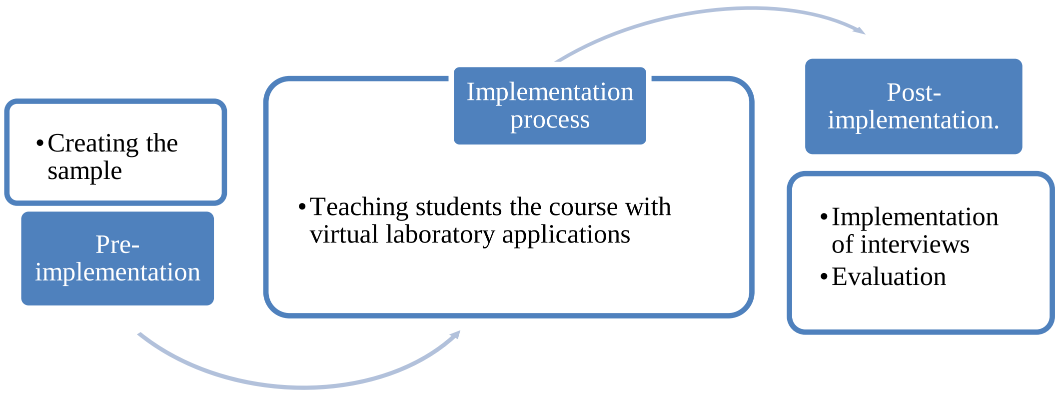

Figure 1. Progress of the study

Pre-implementation

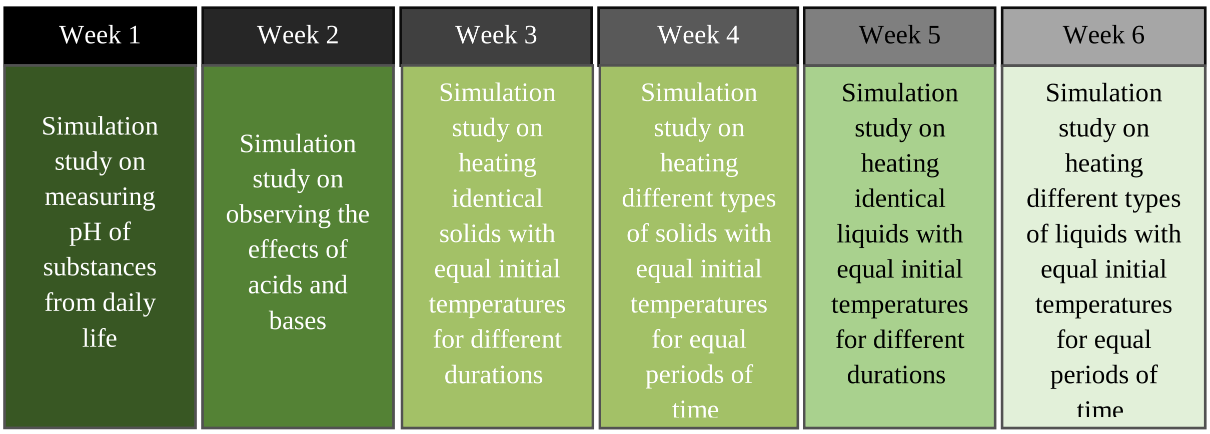

Figure 2. Weekly lesson plan of the study

Before the research, first of all, the necessary permissions were obtained from the Hacettepe University Ethics Committee (Date 14.03.2022, Number E-35853172-399-00002085094) and the Konya Provincial Directorate of National Education (Date 24.12.2021, Number E-83688308-605.99-39786665) for the experimental application.

In addition, when the fall semester of the 2021-2022 academic year started, parental consent forms and student voluntary participation forms were collected and the data collection process was started on a voluntary basis. Pilot applications of the interview form applied within the scope of the study were made and it was finalized for implementation at the end of the process. After the study group was determined, the experimental application process was started and interviews were conducted at the end of the process. Before the application, the teaching processes applied to the students were designed and weekly lesson plans/content (Figure 2) were created.

Implementation process

The group lesson took 6 weeks within the plan prepared in accordance with the subject content in the unit "Matter and Industry/Matter and Nature". The students in the sample carried out the experiments in a virtual laboratory environment. Activities prepared by the researcher were carried out for two hours per week.

Figure 3. Examples of virtual laboratory applications

For the research, 3D virtual laboratory activities were prepared using the Unity program (Figure 4).

Figure 4. Virtual laboratory experiments

Post-implementation.

At the end of the lesson explanation and the following virtual laboratory applications, a semi-structured interview was conducted. The data collection and implementation process of the research lasted 9 weeks in total. The process ended with the determination of students in the first week, the implementation of pilot studies in the second week, the implementation of activities with the sample for 6 weeks, and the implementation of semi-structured interviews in the last week.

Results and Discussion

Within the scope of the research, semi-structured interview questions were prepared as a qualitative data collection tool and face-to-face interviews were conducted with the students. Using a semi-structured interview form, the students were asked about the strengths and weaknesses of the applications, taking into account their computational thinking skills. Because in the semi-structured interview technique, the researcher continues with the interview protocol he/she has prepared in advance and provides more expected and systematic information, which makes it easier than unstructured interviews (Yıldırım & Şimşek, 2021). The interviews lasted between 15-20 minutes. The questions asked to the interviewers are given below;

1. If you wanted to make such an application, which subjects would you like to use it in? (Creativity)
2. In which courses would you like to use this application? (Creativity)
3. Were you able to follow the application steps of the program? Were the instructions sufficient? (Algorithmic thinking)
4. Were you alone or with your friends while implementing the program? Was it fun to play with your friends? (Collaboration)
5. What are the features of the application that you liked? (Critical thinking)
6. What are the features of the application that need to be improved? (Critical thinking)
7. Were there any problems you encountered during the application? What did you do to overcome them? (Problem solving)
8. What are your general thoughts about the virtual laboratory?

The answers given by the students are shared below as examples.

1. If you wanted to do such an application, what topics would you like to use? (Creativity)

S1; It could be the angle at which the sun's rays fall on the Earth.
S2; It could be about DNA and heredity.
S3; It could be about simple machines. Especially screws and pulleys.
S4; It could be about simple machines.
S5; It could be about seasons and climate.

2. In which classes would you like to use this application? (Creativity)

S1; Mathematics.
S2; I would like it to be prepared, but it wouldn't be as good as science. For example, what can you do in grammar?
S3; There could be animation in history class.
S4; It could be in English and history classes.
S5; It would be good in math and English classes.

3. Were you able to follow the application steps of the program? Were the instructions sufficient? (Algorithmic thinking)

S1; I was a little confused at first but then I figured it out. It is difficult to proceed without reading the texts. Yes, the instructions were sufficient but it is impossible to proceed without reading.
S2; I had difficulty during the first application but it was not a problem since I had the opportunity to repeat it many times.
S3; Yes, it was easy in my opinion. The instructions were sufficient. It would have been nice if the texts were supported by audio.
S4; Yes, it was not a problem. In fact, I think the texts were more than necessary. I could do the experiment I wanted in some activities but in others I had to do what you wanted.
S5; Since I covered the topics in class and then did the activity, I think it was not a problem. However, for someone who does not know the topics, the student may not know what to do in some activities. The texts were sufficient for someone who knows the topic.

4. Were you alone or with your friends when you implemented the program? Was it fun to play with your friends? (Collaboration)

S1; Yes, we did it with friends at school. I had a hard time at first, X showed me. I did it at home by myself. It's more fun to do it with my friend.
S2; I did it both at school and at home. It's more fun to do it with friends, and the image was better on the computer at school. The image was bad at home.
S3; It's more fun to do it with my friends at school. In fact, I wish we could do it with 3-4 friends at the same time. It's like playing an online game.
S4; I didn't quite understand it at school. We did it with my brother at home. I think it's more fun to do it at home.
S5; I did it with my computer at home. It could have been fun when I was with my friends, but I couldn't do it as much. I would be embarrassed in front of them.

5. What are the features of the application that you like? (Critical thinking)

S1; It is fun; it can be repeated many times.
S2; It is 3-dimensional, it feels like a real laboratory, unlimited experiments can be done.
S3; It can be practiced many times, it asks for results, it gives feedback, the heat-temperature graphs move simultaneously.
S4; You can do it whenever you want, as much as you want, it includes safety precautions, you wear glasses, you wear gloves, it includes real subjects.
S5; It is 3-dimensional and realistic, it complements school lessons, it offers the opportunity to experiment at home.

6. What are the features of the application that need to be improved? (Critical thinking)

S1; Sometimes it slows down.
S2; There are problems while moving the mouse, the graphics are low.
S3; No sound effects, no sound effects in feedback or approval. Texts are not supported by sound.
S4; The mouse is too fast, there are many instructions.
S5; Some experiments are too long; some experiments are too short.

7. Did you encounter any problems during the application? What did you do to overcome them? (Problem solving)

S1; At first I had a hard time understanding. But as I said, X showed me. Then I solved it myself.
S2; No, I didn't encounter any problems.
S3; I didn't encounter any problems. It's very well prepared.
S4; I had a hard time getting used to the mouse. It was moving very fast. My brother slowed down the speed of the mouse on the computer at home. Then I didn't encounter any other problems.
S5; In the heat-temperature experiments, the graphs of the liquids were not very readable. You have to go to the graph tables and examine them.

8. What are your general thoughts about the virtual lab?

S1; I think it was very good. It made it easier for us to understand the topics. I really liked it.
S2; Instead of giving you the information, it wanted you to find it. It told you to do it. Even if it was wrong, it would start over. It was very successful.
S3; I liked it. It was nice that we could do it and see the results at the same time. It was nice to do it where and when we wanted.
S4; I think the security measures given at the beginning of the game were a good idea. I liked it very much in general.
S5; It allowed us to practice the topics even if we didn't understand them. I think it was useful in solving the questions. It is nice that it covers the same topics as the lessons.

Conclusion

When the student responses are examined, it is seen that the students liked the virtual laboratory applications. The students liked the idea and flow of the application and found the instructions sufficient. They requested more similar applications after the lecture in science classes and even said that it could be good in different branches. This view is similar to the study of Rutten et al. (2012) in which they stated that simulations are not sufficient on their own but can play an important role in making laboratory activities more effective by presenting them as a pre-laboratory training in areas where they are already accepted as an educational tool (such as flight simulation) before moving on to real activities. It also supports the study of Turgut et al. (2012) in which they suggested that instead of using pre-determined experiment process and result sheets in laboratory classes, alternative laboratory applications should be implemented by going beyond the routine.

They saw the application being fun, being able to be repeated many times and providing feedback as positive aspects. This result was also observed by the mediator. In the study, it was observed that the students learned to perform the operations in order by working repeatedly through trial and error. It was observed that the students created the coding in their minds and applied it in the experiments they would conduct. In line with these findings, it was concluded that the students' algorithmic thinking skills were effective during the 3D virtual laboratory activities. It was observed that the students developed creative solutions to problems they had not encountered before and followed the steps to be taken regarding the problems in a logical order. It was observed that the students did not only perform the applications given to them during the process of performing the activities, but also detected the errors they encountered and gave ideas on how to eliminate them. These results are parallel to the result that Zhou et al. (2011) found in their research that it contributed to the solution of the problem of not being able to sufficiently establish the relationship between experiments and physics theories. In addition, it is consistent with the research of de Jong et al. (2013) that students were able to perform more than one experiment with virtual laboratory activities and that they performed the operations they needed to do each time in a shorter time.

Students stated that they enjoyed doing activities with their friends in the classroom environment. This is supported by the study of Santdl (2016) where students stated that they were useful and productive when they worked as a team. It is also consistent with the study of Tang et al. (2020) that teamwork is important. During virtual laboratory applications, it was observed that students reasoned according to the experimental results and associated them with examples they encountered in daily life. This inference is similar to the study of Özden and Bozkurt (2024). In addition, questions related to the subject were asked in the interviews conducted with the students at the end of the application and discussion sessions were organized. The students' positive and negative views about the activities were examined and it was observed that they could give more detailed answers on generalizations and justifications from the experiments. For these reasons, it can be said that it was effective in revealing the students' critical thinking skills. It was also observed that the students who completed the activities had high self-confidence and could express their feelings and thoughts easily. The graphics in the application attracted their attention. They criticized the fact that it was a little slower and the graphic resolutions decreased when they used it at home. These results were found to be similar to other studies on virtual laboratories (Azizah & Alonysius, 2021; Barr & Stephenson, 2011; Berland & Lee, 2011; Chen, 2010; Chopra et al., 2017; de Jong et al., 2013; Ergüzeloğlu & Kaplan, 2021; Karagöz-Mırçık & Saka, 2016; Kavlak & Birhanlı, 2023; Önder et al., 2023; Özden & Bozkurt, 2024; Rutten et al., 2012; Standl, 2016; Tang et al., 2020; Tsakeni, 2021; Turgut et al., 2012; Yaday et al., 2017; Zhou et al., 2011).

Recommendations

In the interviews with the students, they stated that it would be nice to do activities on DNA, seasons and simple machines in addition to the activities on heat-temperature and acid-bases in science classes. They also wanted animations to be done in math, history and English classes. They also think that adding sound and music to the new research planned to be done will increase the appeal of the application.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS Journal belongs to the authors.

Acknowledgements or Notes

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