TURJE
www.turje.org

2023
Volume: 12 Issue: 2

Turkish Journal of Education

https://doi.org/10.19128/turje.1252402
Research Article

Received 17.02.2023
Accepted 18.03.2023

Investigating the effects of different laboratory environments on gifted students' conceptual knowledge and science process skills

Hasan Ozgur Kapici
Bogazici University, Faculty of Education, Istanbul, Türkiye, hasanozgur.kapici@boun.edu.tr
Fatma Costu
Istanbul Sabahattin Zaim University, Istanbul, Türkiye, fatmacostu@gmail.com

ABSTRACT Instructional technology has been developing rapidly and its impacts can be observed in learning environments. One of the recent technological tools used in science classes is virtual laboratories. This study aims to investigate the effects of virtual laboratories on developing gifted students' conceptual knowledge and improving science process skills. A total of 60 sixth-grade gifted students were the participants. Half of the students were in the control group, in which hands-on experimentation was followed, and the other 30 sixth-grade students were involved in the experimental group, in which virtual laboratory environments were used. Two different instruments, a multiple-choice conceptual knowledge test, and a science process skills test, were used in this study. The findings indicated that each condition increased their content knowledge and enhanced their science process skills in the study. However, the gifted learners in the virtual laboratory environment performed better than those in the hands-on laboratory environment for both tests. Possible reasons for the findings and some suggestions were also shared in the discussion.

Keywords: *Gifted learners, Hands-on laboratory, Inquiry learning, Virtual laboratory*

Farklı laboratuvar ortamlarının üstün yetenekli öğrencilerin kavramsal bilgilerine ve bilimsel süreç becerilerine etkisinin incelenmesi

ÖZ Teknolojideki gelişmeler etkilerini eğitim alanında da göstermektedir. Bu kapsamda özellikle son yıllarda sanal laboratuvarlar okullarda kullanılmaya başlanmıştır. Bu çalışmada sanal laboratuvar ve fiziksel uygulamalı laboratuvarlarda öğrenim gören üstün yetenekli 6. sınıf ortaokul öğrencilerinin kavramsal bilgilerindeki ve bilimsel süreç becerilerindeki değişimin incelenmesi amaçlanmıştır. Çalışmaya 60 üstün yetenekli altıncı sınıf öğrencisi katılmıştır. Katılımcıların 30'u deney grubunda, diğer 30'u da kontrol grubunda yer almıştır. Çoktan seçmeli kavramsal bilgi testi ve bilimsel süreç beceri testi olmak üzere iki farklı veri toplama aracı kullanılmıştır. Çalışmanın sonuçlarına göre her iki gruptaki öğrenciler de kavramsal bilgilerini ve bilimsel süreç becerilerini anlamlı şekilde arttırmıştır. Bununla birlikte sanal laboratuvarda öğrenim gören üstün yetenekli öğrencilerin fiziksel uygulamalı laboratuvardaki öğrencilere göre daha iyi performans gösterdikleri sonucuna varılmıştır. Bu sonuçla ilgili olası nedenler ve bazı önerilerde bulunulmuştur.

Anahtar Sözcükler: *Sanal laboratuvar, Sorgulamaya dayalı öğrenme, Uygulamalı laboratuvarlar, Üstün yetenekli öğrenciler*

Citation: Kapici, H.Ö., & Costu, F. (2023). Investigating the effects of different laboratory environments on gifted students' conceptual knowledge and science process skills. *Turkish Journal of Education, 12*(2), 94-105. https://doi.org/10.19128/turje.1252402

INTRODUCTION

Instructional technology has been developing rapidly and its impacts can be observed in learning environments. Online learning platforms, simulations, and virtual laboratories are several examples of instructional technologies used in classes. Science education is one of the fundamental courses that have been impacted by educational technology because science curriculums involve many subjects that can be taught better using instructional technology. For example, it is very difficult to teach some topics in science meaningfully without experimentation in school science laboratories (Lunetta et al., 2007). However, it is not possible to do experiments for each topic in science curriculums due to several reasons such as the nature of the topic, lack of equipment, or time restrictions. Because of these limitations, teachers can make use of instructional technology, such as virtual laboratories, in their science classes. In the last, many studies were conducted to investigate the impacts of virtual laboratories on students' conceptual knowledge and/or understanding (Darrah et al., 2014; Hensen et al., 2020; Kapici et al., 2019), science process skills (Mustafa & Trudel, 2013), attitude toward science laboratories (Kapici et al., 2020), or affective domains (Hensen & Barbera, 2019) when compared to hands-on laboratories.

Adapting education with respect to the needs of gifted students is one of the effective ways to stimulate them to improve their talent (Dai & Chen, 2013; Eysink et al., 2015). If appropriate challenges are presented, they may demonstrate higher motivation for learning (Phillips & Lindsay, 2006). Also, they are willing to work on complex problems as they are good problem solvers (Scager et al., 2013; Steiner & Carr, 2003). A type of learning environment matching the learning characteristics and instructional needs of gifted students is inquiry learning (Eysink et al., 2015, p. 64). Based on these, in this study, the effects of using virtual and hands-on laboratories to increase gifted learners' conceptual knowledge about the topic of mirrors and refraction of light, and science process skills were investigated.

Theoretical Background

Science laboratories as inquiry-based learning environments

School science laboratories are one of the most effective environments for learning by inquiry (Minner et al., 2010). Moreover, in addition to increasing students' content knowledge, inquiry-based science laboratories are also beneficial for improving students' psychomotor skills, getting familiar with handling measurement errors, or developing skills in how to design an experiment and gather data (Burkett & Smith, 2016; Kontra et al., 2015; Puntambekar et al., 2021; Zacharia, 2015). Furthermore, the inquiry-based learning (IBL) approach helps learners to identify problems, design and implement investigations, gather and analyze data, make inferences, and assess their own progressive process (van Joolingen & Zacharia, 2009). However, students mostly have difficulties while learning in the inquiry process (de Jong & van Joolingen, 1998). That is why providing guidance has an important function in an IBL environment (Lazonder & Harmsen, 2016). De Jong and Lazonder (2014) introduced mainly six different types of guidance defined by de Jong and Lazonder (2014): the first type of guidance is 'process constraints' that limit or decrease students' activities in a virtual learning environment, the second type is 'a performance dashboard' that shows data about learners' results, the third type is 'prompts' that are used to give specific directions about what to do in the learning process, the fourth one is 'heuristics' that offer recommendations for learners about what they should do, the fifth type is 'scaffolds' that usually provide tools to help students with a learning process for which they lack proficiency (e.g., hypothesis scratchpad), and the sixth type of guidance is 'direct presentation of information', which is generally used when students lack prior knowledge or are unable to reach the information themselves. Teachers should consider their students' prior knowledge, experience, cognitive and affective conditions, and learning environment to decide which type of guidance should be used in an IBL environment.

Different laboratory environments: Hands-on and virtual laboratories

Hands-on laboratory environments are common and have been widely used at schools. It has great advantages for learners' conceptual understanding, domain knowledge, attitudes toward school science laboratories, and inquiry skills. However, teachers sometimes have to handle difficulties in hands-on laboratories (Nivalainen et al., 2010), like the high cost of laboratory equipment and materials, the potential dangers of chemicals, and problems to observe invisible or enormous entities (Scalise et al., 2011).

Virtual laboratories, which have been developed based on improvements in educational technology, have the affordances to provide solutions to these restrictions. For example, virtual laboratories can provide accurate, rapid, and dynamic data display, cost and time efficiency, and a safer environment (Achuthan & Murali, 2015; Puntambekar et al., 2021). They can also convert invisible entities like electricity (Kollöffel & de Jong, 2013) into tangible ones. On the other side, virtual laboratories have several disadvantages. For example, they are not proper to improve teamwork skills since learners often work individually on computers, so students do not need to collaborate with peers (Burkett & Smith, 2016). Furthermore, learners are able to test most of their hypotheses but it is not possible in virtual laboratories since the variables in an experiment depend on the design features of the virtual laboratory (Burkett & Smith, 2016).

To sum up, all types of laboratory environments aim to increase learners' content knowledge and improve their science process skills (National Research Council, 2012). Nonetheless, each laboratory environment has specific properties. Because of this, it is crucial to determine the type of laboratory environment concerning its advantages to enhancing learners' content knowledge (Puntambekar et al., 2021).

Comparison of different laboratory environments concerning content knowledge and science process skills

In the related literature, it is possible to find studies that have examined the impacts of hands-on and virtual laboratories on learners' content knowledge and science process skills. For instance, in the study done by Tatli and Ayas (2013), they reached the conclusion that virtual laboratories are effective as much as hands-on laboratories to teach the topic of chemical changes to high school students. Similarly, Kollöffel and de Jong (2013) designed a study with secondary school students and concluded that learners in the virtual laboratory reached higher score than the ones in the hands-on laboratory environment for conceptual understanding of electric circuits. In the other study, Zacharia and Constantinou (2008) reported that both virtual and hands-on and laboratories are equally effective for teaching the topic of heat and temperature to undergraduate students. On the other hand, there are also some other studies (e.g., Gire et al, 2010) which have concluded that hands-on laboratory environments provide better opportunities to learners than virtual laboratories. Nonetheless, most of the meta-analyses related to the comparison of virtual and hands-on laboratories (e.g., Brinson, 2015) have concluded that virtual laboratory environments provide equal or greater opportunities for students' achievement and conceptual understanding.

Not only conceptual knowledge but also the impacts of virtual and hands-on laboratories on students' science process skills have been investigated. For instance, Yang and Heh (2007) found that high school students who used the virtual laboratory enhanced their science process skills significantly higher than the students in the hands-on laboratory. A study by Mutlu and Acar-Şeşen (2016) also supported this result. They reached the conclusion that the virtual laboratory environment provided pre-service science teachers with the opportunity to develop their science process skills significantly better than the hands-on laboratory environment. In another study, Lee and colleagues (2002) concluded that pre-service teachers found that the simulation helped them to develop their inquiry skills. On the other hand, there are also studies (Kapici et al., 2019) that concluded that both types of laboratory environments have similar impacts to improve learners' science process skills.

Most of the studies related to IBL-based hands-on and virtual laboratories have been done with participants from kindergarten to undergraduate students (Zacharia & de Jong, 2014). However, it is difficult to find studies that have investigated how virtual laboratories work for gifted students' conceptual knowledge and science process skills. Examining and revealing how gifted students learn from virtual laboratories is a crucial issue not only to contribute to the related literature but also to be able to design better learning environments for them to enable them to show their potential better. Gifted students are open to authentic tasks with high levels of abstraction and complexity and inquiry-based virtual laboratories are adaptive, which means they have the potential to challenge gifted learners (Eysink et al., 2015); so, such kind of laboratory environments may help gifted students to increase their potential. That is why it is important to investigate how gifted students learn and improve their skills in inquiry-based virtual laboratories. Furthermore, gifted students in both hands-on and virtual laboratories are not supported with structured guidance because as reported by Kanevsky (2011) those learners prefer to work more in open-ended environments than in structured environments. Based on this context, the research question was determined as follows:

- Is there an effect of different inquiry-based laboratory environments (hands-on vs. virtual) in terms of gifted students' learning about the mirrors and refraction of light, and improving their science process skills?

METHOD

Participants

The study was done with 60 gifted sixth-grade students. The students were from a Science and Art Center, where gifted students are able to attend. The same science teacher taught the students in hands-on and virtual laboratories. Half of the students were in the control group, in which hands-on experimentation was followed, and the other 30 sixth-grade students were involved in the experimental group, in which virtual laboratory environments were used. The Ethics Committee approval was provided by the Institutional Review Board in Social Science and Humanities at Bogazici University (Number: E-84391427-050.01.04-104274, Date: 27.12.2022). Convenience sampling was used to choose these participants. Because one of the authors was a science teacher in the Art and Science Center, so it was easy to reach these participants.

Instruments

Two different data-gathering tools were used in the current study. These were multiple-choice conceptual knowledge test and science process test.

Multiple-choice conceptual knowledge test

In order to develop the test, the related studies (Akın Yanmaz, 2021; Benli et al., 2012; Çil & Çepni, 2012; Demirer, 2015; Kocakülah, 2006; Saylan Kırmızıgül, 2019; Ünal Çoban, 2009) in the literature were examined. A total of 17 questions were determined concerning the objectives of the topic taught in the study. The questions on the test are about types of mirrors, refraction, and the properties of images on the different types of mirrors. One point was given for each correct answer, so possible scores that can be reached vary between 0 and 17. The Cronbach's alpha coefficient was .74 for this test.

Science process skills test

The original version of the test is the Test of Integrated Process Skills (TIPS II) developed by Okey et al. (1982). It was translated into Turkish by Geban et al. (1992). Then, Aktamış and Ergin (2007) revised the version for middle school students. This version was used in the current study. The test includes 19 multiple-choice questions. The test aims to evaluate learners' basic science process skills (e.g., prediction, observation, classifying) and higher-order science process skills (e.g., designing experiments, forming a hypothesis). Cronbach's alpha coefficient was .78 for this test.

Research Context

The topic was determined as mirrors and refraction of light since the experiments in the unit were available to be done in both hands-on and virtual laboratories and also there were limited studies in the related literature. Then, six different inquiry learning spaces were developed on the virtual platform. The learning spaces are about plane mirrors, concave mirrors, convex mirrors, and refraction of light. This process was done together with the researcher and the science teacher. Laboratory worksheet, which is similar to the inquiry learning spaces, were also developed for the students in the hands-on laboratory environments. After that, students were divided into two groups randomly. For the students in the virtual laboratory environments, one class hour was organized to introduce the virtual learning environment. In the next step, the tests were implemented as pre-tests. Then, the implementation process was started. The students in experimental and control groups were divided into groups of two randomly**.** The implementation process took five weeks. In the first week, the pre-test administration and the first inquiry learning space (and its equivalent form for the hands-on group) were done. In the second and third weeks, two inquiry learning spaces and their equivalent forms for the hands-on group were used for each week. In the fourth week, whereas students in the virtual laboratory environment did the last inquiry learning space on the computers, its equivalent form was presented through laboratory worksheets to the students in the hands-on laboratory environment. In the implementation process, students in the virtual laboratory environments designed and implemented their investigation in the virtual laboratory on computers. On the other hand, the students in the hands-on laboratory environment did the same experiments by using physical materials in the hands-on laboratory environment. The post-tests were implemented after a week of the implementation process in the fifth week.

Data Analysis

The same approach was used while analyzing the data gathered from both the conceptual knowledge test and the science process skills test. An independent samples *t*-test was used to compare the pre-test and post-test scores of the groups. Furthermore, the pre-test and post-test scores of each group were compared with a paired sample *t*-test.

RESULTS

Firstly, the results of the conceptual knowledge test were given. And then, the findings based on the science process skills test were given. The conceptual knowledge test was administered as both a pre-test and a post-test. Table 1 shows the descriptive results of this test.

Table 1.
Mean Scores for the Conceptual Knowledge Test

	Experimental class (*n*=30) Mean (SD)	Control class (*n*=30) Mean (SD)
Pretest	9.27 (1.20)	10.07 (2.12)
Posttest	15.30 (1.06)	11.97 (2.19)
Difference	6.03 (1.22)	1.90 (1.16)

At the beginning of the study, the groups' pretest scores were compared through the independent sample *t*-test. The outcome revealed that the groups were similar to each other in terms of conceptual knowledge related to mirrors and refraction of light ($t(58)=1.801$, $p=.077$). After the implementation process, the pre-test and post-test scores of each group were compared with the paired sample *t*-test. The findings indicated that both of the groups enhanced their conceptual knowledge related to the topic of mirrors and refraction of light throughout the study (Experimental Group, $t(29)=27.149$, $p=.000$; Control Group, $t(29)=9.009$, $p=.000$). Then, in order to reveal whether there is a statistically significant difference between the control and experimental groups' post-test scores, the independent sample *t*-test was used again. The result showed that the difference in mean scores of both groups is statistically meaningful ($t(58)=7.513$, $p=.000$, $d=1.94$). In other words, the experimental group statistically and meaningfully augmented their score on the conceptual knowledge test more than their control group counterpart.

The same process was followed for the science process skills test. This test was also implemented as both a pre-test and a post-test. Table 2 presents the descriptive data for the science process skills test.

Table 2.
Mean Scores for The Science Process Skills Test

	Experimental class (n=30) Mean (SD)	Control class (n=30) Mean (SD)
Pretest	11.57 (2.86)	12.27 (2.78)
Posttest	16.63 (1.90)	13.40 (2.70)
Difference	5.07 (1.64)	1.13 (.68)

First of all, the control and experimental groups' pre-test scores were contrasted by the independent sample *t*-test. The outcomes indicated that the students in both groups have similar inquiry skills ($t(58)=.961$, $p=.340$). Finally, the paired sample *t*-test was operated to analyze the control and experimental groups' pre-test and post-test scores. The results revealed that both conditions improved their inquiry skills from the beginning to the end of the study (Experimental Group, $t(29)=16.936$, $p=.000$; Control Group, $t(29)=9.109$, $p=.000$). After that, the groups' post-test scores were contrasted with each other by the independent sample *t*-test, again. The outcomes revealed that the experimental group enhanced their science process skills more than the control group ($t(58)=5.364$, $p=.000$, $d=1.38$).

DISCUSSION

The effects of virtual laboratories on gifted sixth-grade students' conceptual knowledge about the mirrors and refraction of light, and their science process skills, when compared to hands-on laboratory environments, were investigated in this study. The results showed that although both groups enhanced their conceptual knowledge and improved their science process skills throughout the study, the students in the experimental group reached significantly higher scores than their control group counterparts in both of the tests. There are also studies in the literature that support the view that virtual laboratories can be efficient in a learning process at least as much as hands-on laboratories (Kollöffel & de Jong, 2013; Tüysüz, 2010).

The participants of this study are gifted students which makes this study different from the others. The findings revealed that gifted students statistically, significantly enhanced their conceptual knowledge and science process skills in both inquiry-based hands-on and virtual laboratories. Students received guidance in both conditions, so this can be a major source of success for gifted students in inquiry-based hands-on, and virtual laboratories. In the hypothesis development, designing, and implementing investigation phases of an inquiry cycle, students in both conditions received guidance with respect to their conditions. In other words, they received guidance via the laboratory worksheet in written form, if they were in the hands-on laboratory environment. On the other hand, they used online scaffolding tools in the same inquiry stages, if they were in the virtual laboratory environment. Eysink and colleagues (2015) stated that gifted students can also need guidance in inquiry-based learning environments and if they are provided with suitable support their potential can enlarge.

The results of the science process skills tests revealed that gifted learners in both conditions improved their science process skills meaningfully. However, the ones in the virtual laboratory environments enhanced their science process skills better than the ones in the hands-on laboratory environments. The difference between gifted students' science process skills in hands-on and virtual laboratories can be due to the affordances of the virtual laboratory environments. Students in the virtual laboratory environment used hypothesis scratchpad and experiment design tool during inquiry learning and these tools can be more useful than their written corresponding ones in the laboratory worksheet, which were used by the students in the hands-on laboratory environment. Furthermore, in the related literature, it is possible to find studies (e.g., Mutlu & Acar-Şeşen, 2016; Yang & Heh, 2007) that stated that virtual laboratories can also be proper environments to improve students' science process skills like hands-on laboratory environments.

To sum up, gifted students can also learn better and improve their science process skills significantly in virtual laboratories. When the superiorities of virtual laboratories are taken into consideration such as transforming intangible concepts into concrete forms and presenting the core by removing the detailed knowledge, cost, and time efficiency, they can be used frequently for teaching gifted learners. This does not mean that hands-on laboratories are useless or ineffective. Hands-on and virtual laboratories can complement each other. Although both laboratory environments have common goals such as enhancing students' content knowledge, each has its own properties. For example, hands-on laboratories are effective to improve students' psychomotor skills. However, in order to reach such positive outcomes, providing proper guidance to students is a necessity (for more see de Jong & Lazonder, 2014). Although the participants in the current study were gifted students, they nevertheless needed guidance while studying the topic.

Science teachers have a crucial role because they decide which type of laboratory environments to use for their class(es). Thus, it is important to know the advantages and drawbacks of different laboratory environments. In this way, the teacher can take proper decision about the laboratory environment to use while teaching the topic. Furthermore, the teacher should know the objectives of the unit in order to be able to determine which objective can be taught better in which laboratory environment. The physical condition and facilities of the school are other important issues when choosing the laboratory environment to use.

CONCLUSION

In this study, it was concluded that virtual laboratories are also a proper instructional tool like hands-on laboratories for gifted learners. Although the learners in the virtual laboratory environments increased their domain knowledge and enhanced their science process skills better than the students in the hands-on laboratories, it is difficult to make absolute comments concerning the outcomes of just a single study. Many more studies should be done. It is difficult to find studies done with gifted learners in inquiry-based virtual laboratories. That is why similar studies should be designed with different topics and different grades. Furthermore, gifted learners' perceptions and perspectives about virtual laboratories can be investigated. The effectiveness of online scaffolding tools used by gifted students in inquiry-based virtual laboratories can be examined. Last but not least, it is not an absolutely correct conclusion that virtual laboratories are better than hands-on ones. Both complement and support each other. A science teacher has an important function in deciding when to use hands-on and when to use virtual laboratories.

Lastly, the results of this study should be taken into consideration by taking the study's limitations into account. The basic limitation of the current study was that the same tests were administered as a pretest and a posttest. In addition, it was the first time the learners used virtual laboratories. There were a limited number of participants in each condition.

REFERENCES

Achuthan, K., & Murali, S. S. (2015). A comparative study of educational laboratories from cost and learning effectiveness perspective. In R. Silhavy, R. Senkerik, Z. K. Oplatkova, Z. Prokopova, & P. Silhavy (Eds.), *Software Engineering in Intelligent Systems: Advances in Intelligent Systems and Computing* (pp. 143-153). Springer. https://doi.org/10.1007/978-3-319-18473-9_15

Akın Yanmaz, E. (2021). *Bağlam temelli öğrenme yaklaşımına göre geliştirilen rehber materyallerin ortaokul 7.sınıf öğrencilerinin kavramsal anlamaları üzerine etkisi: "Aynalar ve ışığın soğurulması" etkinliği [The effect of guide materials developed according to context-based learning approach on the conceptual understanding of 7th grade student: "Mirrors and absorption of light"]* [Unpublished master thesis]. Giresun University.

Aktamış, H., & Ergin, Ö. (2007). Bilimsel süreç becerileri ile bilimsel yaratıcılık arasındaki ilişkinin belirlenmesi [Investigating the relationship between science process skills and scientific creativity]. *Hacettepe University Journal of Education*, *33*, 11-23.

Benli, E., Kayabaşı, Y., & Sarıkaya, M. (2012). İlköğretim 7.sınıf öğrencilerinin fen ve teknoloji dersi "ışık" ünitesinde teknoloji destekli öğretimin öğrencilerin fen başarısına, kalıcılığa ve fene karşı tutumlarına etkisi [The effect of supported science education to the science achievement, the permanence of knowledge and the attitudes toward science of 7th grade students]. *Gazi University Journal of Gazi Education Faculty*, *32*(3), 733-760.

Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. *Computers & Education, 87*, 218-237. https://doi.org/10.1016/j.compedu.2015.07.003

Burkett, V. C. & Smith, C. (2016). Simulated vs. hands-on laboratory position paper. *Electronic Journal of Science Education*, *20*(9), 8-24.

Çil, E., & Çepni, S. (2012). The effectiveness of the conceptual change approach, explicit reflective approach, and course book by the ministry of education on the views of the nature of science and conceptual change in light unit. *Educational Sciences: Theory & Practice*, *12*(2), 1107-1113.

Dai, D. Y., & Chen, F. (2013). Three paradigms of gifted education: In search of conceptual clarity in research and practice. *Gifted Child Quarterly*, *57*(3), 151-168. https://doi.org/10.1177/0016986213490020

Darrah, M., Humbert, R., Finstein, J., Simon, M., & Hopkins, J. (2014). Are virtual labs as effective as hands-on labs for undergraduate physics? A comparative study at two major universities. *Journal of Science Education and Technology*, *23*(6), 803-814. https://doi.org/10.1007/s10956-014-9513-9

de Jong, T., & Lazonder, A. (2014). The guided discovery principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (2nd ed., pp. 371-390). Cambridge University Press. https://doi.org/10.1017/cbo9781139547369.019

de Jong, T., & Van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research*, *68*(2), 179-201. https://doi.org/10.3102/00346543068002179

Demirer, G. M. (2015). *Kavram yanılgılarının giderilmesinde simülasyonların etkisinin incelenmesi: ışık ve ses ünitesi örneği [The effect of simulations on the elimination of misconceptions: Light and sound unit sample]* [Unpublished master thesis]. Kırıkkale University.

Eysink, T. H. S., Gersen, L., & Gijlers, H. (2015). Inquiry learning for gifted students. *High Ability Studies*, *26*(1), 63-74. https://doi.org/10.1080/13598139.2015.1038379

Geban, Ö., Askar, P., & Özkan, İ. (1992). Effects of computer simulations and problem-solving approaches on high school students. *The Journal of Educational Research*, *86*(1), 5-10. https://doi.org/10.1080/00220671.1992.9941821

Gire, E., Carmichael, A., Chini, J. J., Rouinfar, A., Rebello, S., Smith, G., & Puntambekar, S. (2010, June). *The effects of physical and virtual manipulatives on students' conceptual learning about pulleys*. Paper presented at the International Conference of the Learning Sciences, Chicago, IL. https://doi.org/10.1063/1.3680062

Hensen, C., & Barbera, J. (2019). Assessing affective differences between a virtual general chemistry experiment and a similar hands-on experiment. *Journal of Chemical Education, 96*(10), 2097-2108. https://doi.org/10.1021/acs.jchemed.9b00561

Hensen, C., Glinowiecka-Cox, G., & Barbera, J. (2020). Assessing differences between three virtual general chemistry experiments and similar hands-on experiments. *Journal of Chemical Education*, *97*(3), 616-625. https://doi.org/10.1021/acs.jchemed.9b00748

Kapici, H. O., Akcay, H., & de Jong, T. (2019). Using hands-on and virtual laboratories alone or together – which works better for acquiring knowledge and skills? *Journal of Science Education and Technology*, *28*(3), 231-250.

Kapici, H. O., Akcay, H., & de Jong, T. (2020). How different laboratory environments influence students' attitudes toward science courses and laboratories. *Journal of Research on Technology in Education*, *52*(4), 534-549.

Kanevsky, L. (2011). Deferential differentiation: What types of differentiation do students want? *Gifted Child Quarterly*, *55*, 279-299. https://doi.org/10.1177/0016986211422098

Kocakülah, A. (2006). *Geleneksel öğretimin ilk, orta ve yükseköğretim öğrencilerinin görüntü oluşumu ve renklere ilişkin kavramsal anlamalarına etkisi [The effect of traditional teaching on primary, secondary and university students' conceptual understanding of image formation and colors]* [Unpublished doctoral dissertation]. Balıkesir University.

Kollöffel, B., & de Jong, T. (2013). Conceptual understanding of electrical circuits in secondary vocational engineering education: Combining traditional instruction with inquiry learning in a virtual lab. *Journal of Engineering Education*, *102*(3), 375-393. https://doi.org/10.1002/jee.20022

Kontra, C., Lyons, D. J., Fischer, S. M., & Beilock, S. L. (2015). Physical experience enhances science learning. *Psychological Science*, *26*(6), 737-749. https://doi.org/10.1177/0956797615569355

Lazonder, A. W., & Harmsen, R. (2016). Meta-analysis of inquiry-based learning: Effects of guidance. *Review of Educational Research, 86*(3), 681-718. https://doi.org/10.3102/0034654315627366

Lee, A. T., Hairston, R. V., Thames, R., Lawrence, T., & Herron, S. S. (2002). Using a computer simulation to teach science process skills to college biology and elementary majors. *Bioscene, 28*(4), 35-42.

Lunetta, V. N., Hofstein, A., & Clough, M. P. (2007). Learning and teaching in the school science laboratory: An analysis of research, theory, and practice. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 393-441). Routledge.

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—What is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching*, *47*(4), 474-496. https://doi.org/10.1002/tea.20347

Mustafa, M. I., & Trudel, L. (2013). The impact of cognitive tools on the development of the inquiry skills of high school students in physics. *International Journal of Advanced Computer Science and Applications*, *4*(9), 124-129. https://doi.org/10.14569/ijacsa.2013.040920

Mutlu, A., & Acar-Şeşen, B. (2016, June). *Impact of virtual chemistry laboratory instruction on pre-service science teachers' scientific process skills*. Paper presented at the ERPA International Congress on Education, Athens, Greece.

Nivalainen, V., Asikainen, M. A., Sormunen, K., & Hirvonen, P. E. (2010). Preservice and inservice teachers' challenges in the planning of the practical work. *Journal of Science Teacher Education*, *21*, 393-409. https://doi.org/10.1007/s10972-010-9186-z

NRC (National Research Council). (2012). *A framework K-12 science education*: *Practices, crosscutting concepts, and core ideas*. National Academy Press.

Okey, J. R., Wise, K. C., & Burns, J. C. (1982). *Test of Integrated Process Skills* (*TIPS II*). The University of Georgia, Department of Science Education.

Phillips, N., & Lindsay, G. (2006). Motivation in gifted students. *High Ability Studies*, *17*, 57-73. https://doi.org/10.1080/13598130600947119

Puntambekar, S., Gnesdilow, D., Tissenbaum, C. D., Narayanan, N. H., Rebello, N. S. (2021). Supporting middle school students' science talk: A comparison of physical and virtual labs. *Journal of Research in Science Teaching*, *58*(3), 392-419. https://doi.org/10.1002/tea.21664

Saylan Kırmızıgül, A. (2019). *Fen eğitiminde bilgisayar destekli, etkinlik temelli ve sorgulamaya dayalı öğretim yaklaşımlarının karşılaştırılması [The comparison of computer-aided, activity-based and inquiry-based teaching approaches in science education]* [Unpublished doctoral dissertation]. Erciyes University.

Scager, K., Akkerman, S. F., Pilot, A., & Wubbels, T. (2013). How to persuade honors students to go to the extra mile: Creating a challenge learning environment. *High Ability Studies*, *24*, 115-134. https://doi.org/10.1080/13598139.2013.841092

Scalise, K., Timms, M., Moorjani, A., Clark, L., Holtermann, K., & Irvin, P. S. (2011). Student learning in science simulations: Design features that promote learning gains. *Journal of Research in Science Teaching*, *48*, 1050-1078. https://doi.org/10.1002/tea.20437

Steiner, H. H., & Carr, M. (2003). Cognitive development in gifted children: Toward a more precise understanding of emerging differences in intelligence. *Educational Psychology Review*, *15*, 215-246.

Tatli, Z., & Ayas, A. (2013). Effect of a virtual chemistry laboratory on students' achievement. *Journal of Educational Technology & Society*, *16*(1), 159-170.

Tüysüz, C. (2010). The effect of the virtual laboratory on students' achievement and attitude in chemistry. *International Online Journal of Educational Sciences*, *2*(1), 37-53.

Ünal Çoban, G. (2009). *Modellemeye dayalı fen öğretiminin öğrencilerin kavramsal anlama düzeylerine, bilimsel süreç becerilerine, bilimsel bilgi ve varlık anlayışlarına etkisi: 7.sınıf ışık ünitesi örneği [The effects of model based science education on students' conceptual understanding, science process skills,* *understanding of scientific knowledge and its domain of existence: The sample of 7th grade unit of light]*. [Unpublished doctoral dissertation]. Dokuz Eylul University. https://doi.org/10.53444/deubefd.550710

van Joolingen, W. R., & Zacharia, Z. C. (2009). Developments in inquiry learning. In N. Balacheff, S. Ludvigsen, T. de Jong, A. Lazonder, & S. Barnes (Eds.), *Technology-enhanced learning: Principles and products* (pp. 21-37). Springer. https://doi.org/10.1007/978-1-4020-9827-7

Yang, K.-Y., & Heh, J.-S. (2007). The impact of internet virtual physics laboratory instruction on the achievement in physics, science process skills and computer attitudes of 10th-grade students. *Journal of Science Education and Technology, 16*(5), 451-461. https://doi.org/10.1007/s10956-007-9062-6

Zacharia, Z. C. (2015). Examining whether touch sensory feedback is necessary for science learning through experimentation: A literature review of two different lines of research across K-16. *Educational Research Review, 16*, 116-137. https://doi.org/10.1016/j.edurev.2015.10.001

Zacharia, Z. C., & Constantinou, C. P. (2008). Comparing the influence of physical and virtual manipulatives in the context of the Physics by Inquiry curriculum: The case of undergraduate students' conceptual understanding of heat and temperature. *American Journal of Physics, 76*(4), 425-430. https://doi.org/10.1119/1.2885059

Zacharia, Z. C., & de Jong, T. (2014). The effects on students' conceptual understanding of electric circuits of introducing virtual manipulatives within a physical manipulatives-oriented curriculum. *Cognition and Instruction*, *32*(2), 101-158. https://doi.org/10.1080/07370008.2014.887083

TÜRKÇE GENİŞLETİLMİŞ ÖZET

Öğretim teknolojisi hızla gelişmekte ve etkileri öğrenme ortamlarında gözlenebilmektedir. Çevrimiçi öğrenme platformları, simülasyonlar ve sanal laboratuvarlar, sınıflarda kullanılan öğretim teknolojilerine birkaç örnektir. Fen eğitimi, eğitim teknolojisinden etkilenen temel derslerden biridir. Çünkü fen müfredatları, öğretim teknolojisi kullanılarak daha iyi öğretilebilecek birçok konuyu içerir. Örneğin fen bilimlerindeki bazı konuların okul fen laboratuvarlarında deney yapılmadan anlamlı bir şekilde öğretilmesi çok zordur (Lunetta vd., 2007). Ancak fen bilimleri öğretim programlarında konunun doğası, araç-gereç yetersizliği, süre kısıtlaması gibi çeşitli nedenlerle her konu için deney yapmak mümkün olmamaktadır. Bu sınırlamalar nedeniyle, öğretmenler fen derslerinde sanal laboratuvarlar gibi öğretim teknolojilerinden yararlanabilmektedirler. Özellikle de COVID 19 pandemisiyle beraber son yıllarda sanal laboratuvarların eğitim ortamlarında kullanım sıklıkları artmıştır. Sanal laboratuvarların öğrencilerin kavramsal bilgileri ve/veya anlamaları (Darrah vd., 2014; Hensen vd., 2020; Kapici vd., 2019), bilimsel süreç becerileri (Mustafa ve Trudel, 2013), fen laboratuvarlarına yönelik tutum (Kapici vd., 2020) veya duyuşsal özelliklerine (Hensen ve Barbera, 2019) etkisini araştıran çalışmalar mevcuttur. Yapılan çalışmalarda sanal laboratuvarların da fiziksel uygulamalı laboratuvarlar kadar öğrencilerin kavramsal anlamalarına ve bilimsel süreç becerilerine olumlu katkısının olduğu gösterilmiştir. Sanal laboratuvarlar ilgili alanyazında okul öncesi dönemden üniversite öğrencilerine kadar geniş yelpazeden öğrencilerle denenmişken üstün yetenekli öğrencilerin dahil olduğu bu tip çalışmalar sınırlı sayıda bulunmaktadır.

Eğitimin üstün yetenekli öğrencilerin ihtiyaçlarına göre uyarlanması, onların yeteneklerini geliştirmeye teşvik etmenin etkili yollarından biridir (Dai ve Chen, 2013; Eysink vd., 2015). Eğer öğrenme ortamı ve materyaller uygun zorluk seviyesinde olursa, üstün yetenekli öğrenciler öğrenme için daha yüksek motivasyona sahip olabilirler (Phillips ve Lindsay, 2006). Üstün yetenekli öğrenciler ayrıca iyi birer problem çözücü oldukları için karmaşık problemler üzerinde çalışmaya isteklidirler (Scager vd., 2013; Steiner ve Carr, 2003). Sorgulamaya dayalı öğrenme yaklaşımı üstün yetenekli öğrencilerin öğrenme özelliklerini ve öğretimsel ihtiyaçlarını karşılayan bir öğrenme ortamı türüdür (Eysink vd., 2015). Bunlardan hareketle bu çalışmada sanal laboratuvar ve fiziksel uygulamalı laboratuvarlarda öğrenim gören üstün yetenekli 6.sınıf ortaokul öğrencilerinin kavramsal bilgilerindeki ve bilimsel süreç becerilerindeki değişimin incelenmesi amaçlanmıştır.

Araştırma sorusu olarak da aşağıdaki soru belirlenmiştir.

- Uygulamalı ya da sanal laboratuvar ortamı üstün yetenekli altıncı sınıf öğrencilerinin aynalar ve ışığın kırılması konularını öğrenmelerini ve bilimsel süreç becerilerini geliştirmelerini nasıl etkiler?

Çalışmada nicel araştırma yöntemlerinden olan yarı-deneysel desen kullanılmıştır. İstanbul'da BİLSEM'e kayıtlı 60 öğrenci ile yapılan çalışmada, öğrencilerin 30'u sanal laboratuvar ortamında, diğer 30'u ise fiziksel uygulamalı laboratuvar ortamında öğrenim görmüştür. Her iki gruba da aynı öğretmen öğretim yapmıştır. Çalışmadaki veriler çoktan seçmeli kavramsal bilgi testi ve bilimsel süreç beceri testi ile toplanmıştır. Kavramsal bilgi testi literatürdeki çalışmaların incelenmesi ve öğretilecek konunun kazanımlarına uygun olan sorulardan seçilerek oluşturulmuştur. Testte 17 soru bulunmaktadır. Testin güvenirlik katsayısı .74 olarak bulunmuştur. Bilimsel süreç beceri testi ise literatürde halihazırda kullanılan bir testtir. Testte 19 soru bulunmaktadır ve bu çalışma için güvenirlik katsayısı .78 olarak hesaplanmıştır. Testlerden elde dilen verilerin analizleri bağımlı ve bağımsız örneklem t-testleri kullanılarak yapılmıştır.

Çalışma için aynalar ve ışığın kırılması konusu seçilmiştir. Çünkü bu konudaki deneyler hem uygulamalı hem de sanal laboratuvarlarda yapılabilmesi için uygun. Ayrıca bu konu ile ilgili literatürde sınırlı sayıda çalışma bulunmaktadır. Konu belirlendikten sonra sanal platformda altı farklı sorgulayıcı öğrenme alanı geliştirilmiştir. Bu süreç araştırmacı ve fen bilgisi öğretmeni ile birlikte yürütülmüştür. Uygulamalı laboratuvar ortamlarında öğrenciler için sorgulayıcı öğrenme alanlarının bir benzeri olan deney föyleri geliştirilmiştir. Daha sonra öğrenciler rastgele iki gruba ayrılmıştır. Sanal laboratuvar ortamını kullanacak öğrenciler için sanal öğrenme ortamının tanıtılması için bir ders saati ayrılmıştır. Bir sonraki adımda testler ön test olarak uygulanmıştır. Ardından, uygulama süreci başlamıştır. Her iki gruptaki öğrenciler kendi aralarında rastgele ikişerli gruplara ayrıldı. Uygulama süreci beş hafta sürdü. İlk hafta ön test uygulaması yapıldı ve sanal laboratuvarda öğrenim gören öğrenciler için birinci sorgulayıcı öğrenme alanı (benzer şekilde uygulamalı laboratuvardaki öğrenciler için de deney föyü ile) uygulandı. İkinci ve üçüncü haftalarda, deney grubu için ikişer sorgulama öğrenme alanı ve kontrol grubu için de deney föyü eşliğinde deneyler yapılmıştır. Dördüncü haftada deney grubu öğrencileri sanal laboratuvar ortamında bilgisayarda son sorgulama öğrenme alanını yaparken, uygulamalı laboratuvar ortamında eşdeğer laboratuvar çalışma yaprakları aracılığıyla deney yapılmıştır. Uygulama sürecinden bir hafta sonra beşinci haftada son testler uygulanmıştır.

Çalışmanın sonuçlarına göre her iki gruptaki öğrenciler hem kavramsal bilgilerini hem de bilimsel süreç becerilerine istatistiksel olarak anlamlı şekilde arttırmıştır. Daha sonra her iki gruptaki öğrencilerin test sonuçları bağımsız örneklem t-testi ile karşılaştırılmış ve sanal laboratuvar ortamında öğrenim gören öğrencilerin hem kavram bilgilerini hem de bilimsel süreç becerilerini fiziksel uygulamalı laboratuvarda öğrenim gören öğrencilere göre anlamlı şekilde fazla geliştirdiği sonucuna ulaşılmıştır. Literatürde de buna benzer sonuçlara rastlanmaktadır. Bu çalışma sanal laboratuvarların üstün yetenekli öğrenciler için de verimli öğrenme ortamları sunabileceğini göstermektedir. Her iki gruptaki öğrencilerin hem kavramsal bilgilerinin hem de bilimsel süreç becerilerinin artmasının sebebi sorgulamaya dayalı öğrenme ortamlarında öğrencilere sunulan destekler/rehberlikler olabilir. Sanal laboratuvar ortamında öğrenim gören öğrencilerin kavramsal bilgilerini ve becerilerini daha fazla arttırmasının sebebi sanal laboratuvar ortamlarının sağladığı avantajlar olabilir. Örneğin, sanal laboratuvarlarda öğrencilere çevrimiçi destek araçları sağlanırken, fiziksel uygulamalı laboratuvarlarda öğrencilere bu desteklerin eşlenikleri yazılı olarak laboratuvar föyünde verilmiştir. Öğrenciler çevrimiçi sunulan destekleri daha iyi kullanmış olabilirler. Öte yandan bu sonuçlar bize her koşulda sanal laboratuvarların fiziksel uygulamalı laboratuvarlara göre daha verimli laboratuvarlar olduğunu göstermemektedir. Her iki laboratuvar ortamının da kendine has özellikleri vardır. Birbirlerini tamamlayıcı olarak kullanılabilirler. Bu noktada en önemli görev öğretmenlere düşmektedir. Öğretilecek konunun içeriği, okulun fiziksel durumu ve öğrencilerin bilişsel durumunu göz önüne alarak hangi laboratuvar ortamını kullanacağına ya da her iki laboratuvar ortamını sırayla mı kullanacağına kendisi karar vermelidir.

Son olarak, çalışmanın sonuçları değerlendirilirken sınırlı sayıda öğrencinin yer alması, aynı testlerin hem ön test hem son test olarak kullanılmış olması, çalışmanın süresi gibi sınırlılıklar göz önünde bulundurulmalıdır. Konu hakkında daha derinlemesine bilgi sahibi olmak için benzer çalışmalar farklı sınıf seviyeleri ve farklı konularla yapılabilir. Öğrencilere sunulan destek/rehberlik çeşitleri ve/veya yoğunluğu değiştirilebilir.