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Gifted Pupils' Learning Experience in Virtual Laboratories

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ABSTRACT
One of the main courses that have been affected by instructional technology is science education since the nature of topics covered by the science curriculum may require the usage of technology to teach them better. The aim of the current study was to investigate the effects of virtual laboratories on the development of gifted children's conceptual knowledge and the improvement of inquiry skills. A total of 43 sixth-grade gifted learners were the participants: 22 in the control group, in which hands-on experimentation was conducted, and 21 sixth-grade pupils in the experimental group, where virtual laboratory environments were used. Two different data-gathering tools, namely a multiple-choice conceptual knowledge test and an inquiry skills test, were used in this study. The results revealed that although both groups enhanced their conceptual knowledge and improved their inquiry skills throughout the study, the students in the experimental group reached significantly higher scores than their counterparts for both of the tests. Several suggestions are made for both science teachers and researchers concerning the outcomes of the current study.

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Introduction

There are many facilities provided by instructional technology such as online learning platforms, simulations, and virtual laboratories. One of the main courses that have been affected by instructional technology is science education since the nature of topics covered by the science curriculum may require the usage of technology to demonstrate the subject matter. It is axiomatic that science cannot be properly taught to school learners without experimentation in school science laboratories (Hofstein & Lunetta, 2004; Hofstein & Mamlok-Naaman, 2007). However, it is almost impossible to design and implement investigations for every topic from the science curriculum in school science laboratories such as the topics related to space or microorganisms. That is why instructional technology can be helpful for both teachers and students by providing virtual laboratories. Recently, there are many studies that have examined the effects of virtual laboratories on learners' conceptual understanding (Darrah et al., 2014; Hensen, Glinowiecka-Cox, & Barbera, 2020; Kapici, Akcay, & de Jong, 2019), inquiry skills (Mustafa & Trudel, 2013), and affective domains like attitude toward science laboratories (Hensen & Barbera, 2019; Kapici, Akcay, & de Jong, 2020) when compared to hands-on laboratories.

One of the ways to encourage gifted pupils to improve their talent is by adapting education to their needs as special learners (Dai & Chen, 2013; Eysink, Gersen, & Gijlers, 2015). If they are presented with appropriate challenges, they can develop a higher motivation for learning (Phillips &

Lindsay, 2006). They tend to be eager to work on complex problems because 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 learners is inquiry learning (Eysink et al., 2015, p. 64). In the current study, we focused on the impacts of using hands-on and virtual laboratories to enhance gifted pupils' conceptual knowledge and inquiry skills. The children were at the sixth-grade level and we tested their conceptual knowledge about the topic of force and motion and their inquiry skills in relation to this topic.

Theoretical Background

Inquiry-Based Science Laboratories

One of the most effective ways of learning by inquiry can be achieved through school science laboratories (Minner et al., 2010). Furthermore, inquiry-based science laboratories are not only effective for enhancing content knowledge but also for improving psychomotor skills, how learners deal with measurement errors, and abilities about how to design an experiment and gather data (Burkett & Smith, 2016; Kontra et al., 2015; Puntambekar et al., 2021; Zacharia, 2015). Learners identify problems, design and implement investigations, gather and analyse data, make inferences and assess their own progress in such environments (van Joolingen & Zacharia, 2009). However, the inquiry process can be difficult for school pupils. They may have trouble generating hypotheses, designing and implementing proper experimental procedures, interpreting data, and making conclusions based on the results (de Jong & van Joolingen, 1998). Accordingly, guidance plays a crucial role in an IBL process (Lazonder & Harmsen, 2016). De Jong and Lazonder (2014) defined six types of guidance: 'process constraints' that restrict or reduce pupils' activities in a virtual learning platform, 'a performance dashboard' that provides information about results, 'prompts' that are used to give specific directions about what to do in the learning process, 'heuristics' that provide suggestions about what to do, scaffolds that provide tools in order to help pupils with a learning process for which they lack proficiency (e.g., hypothesis scratchpad), and 'direct presentation of information', which is generally used when they lack prior knowledge or are unable to access requisite information themselves. In order to determine the types of guidance to give learners in an IBL environment, their cognitive and affective attributes and the learning environment should be considered.

Hands-on and Virtual Laboratories as Different Learning Environments

Hands-on laboratory environments have been traditionally used at schools. Although it has an enormous effects on learners' conceptual understanding, science process skills, and attitudes toward school science laboratories, teachers often have to deal with difficulties arising in the 'real-world' laboratory context (Nivalainen et al., 2010), such as the high cost of equipment and materials, potential dangers of chemicals, and problems with observing nebulous phenomena (Scalise et al., 2011).

Virtual laboratories, which have the potential to offer solutions to these restrictions, have started to enter classrooms. Virtual laboratories can provide more time and cost efficiency, rapid, accurate, and dynamic data display, and a safer working environment (Achuthan & Murali, 2015; Puntambekar et al., 2021). It is also possible to transform intangible entities such as electricity (Kollöfel & de Jong, 2013) into tangible forms via virtual laboratories. However, virtual labs do not encourage the development of teamwork skills because learners mostly work individually on computers without collaboration with their peers (Burkett & Smith, 2016). Learners may not be able to test some of their hypotheses since the variables in an experiment depend on the design features of the virtual laboratory (Burkett & Smith, 2016).

Comparison of Hands-on and Virtual Laboratories in Terms of Conceptual Knowledge and Inquiry Skills

There are many studies in the related literature that have investigated the effects of these two different laboratory environments on learners' conceptual knowledge and inquiry skills. For example, Tatli and Ayas (2013) designed and implemented a study with 90 high school pupils to examine the effects of hands-on and virtual laboratory environments on achievement for the topic of chemical changes. They found that the virtual laboratory environment was at least as effective as the hands-on lab environment. A similar study was designed by Kollöfel and de Jong (2013) also with secondary school learners. This time, those in the virtual laboratory group outperformed those in the hands-on laboratory group for conceptual understanding of electric circuits. Zacharia and Constantinou (2008) compared both modes of experimentation with regard to undergraduate students' conceptual understanding about heat and temperature and again found that the two modes were equally effective. However, other researchers have also found that hands-on experimentation is more effective than virtual experimentation. For example, Gire et al. (2010) concluded from their study that experiments done in a hands-on laboratory were more beneficial for undergraduate students' understanding of pulleys than those done in a virtual laboratory. Nevertheless, many of the meta-analyses related to the effectiveness of virtual laboratories (e.g., Brinson, 2015) have revealed that virtual laboratory environments provide equal or greater opportunities for students' achievement and conceptual understanding.

Some researchers have compared the impacts of virtual laboratories on improving learners' inquiry skills when compared to hands-on laboratories. For example, Yang and Heh (2007) found that high school learners who used a virtual laboratory reached significantly higher scores on inquiry skills test than their traditional lab counterparts. In another study, Lee and colleagues (2002) found that pre-service teachers mostly thought that a simulation helped them to develop their inquiry skills. A study by Mutlu and Acar-Şeşen (2016) also supported this view. They found that pre-service science teachers developed their inquiry skills significantly better in the virtual laboratory environment when compared to the hands-on laboratory environment. In contrast, in the study done by Kapici et al. (2019), there was no significant difference in the improvement of seventh-grade pupils' inquiry skills when taught in virtual laboratory environments.

Most of the studies related to IBL-based virtual laboratories have been done with participants from kindergarten children to undergraduate students (Zacharia & de Jong, 2014). A limited number of studies have examined the effects of virtual laboratories on the development of gifted children's conceptual knowledge and the improvement of inquiry skills. Revealing and understanding how gifted learners may benefit from virtual laboratories may aid the design of better learning environments for them. Gifted learners are open to authentic tasks with high levels of abstraction and complexity (Eysink et al., 2015). In other words, they do not like structured environments; they prefer open-ended learning environments (Kanevsky, 2011). It is possible to develop such learning environments in inquiry-based virtual laboratories because they are adaptive. That is why virtual laboratories have the potential to help gifted learners to increase their success and skills. The research question was determined as follows:

- Do gifted sixth-grade pupils who learn the topic of force and motion in a hands-on or in a virtual laboratory environment differ in their acquisition of conceptual knowledge and inquiry skills?

Method

Participants

The study was conducted with 43 gifted sixth-grade pupils from a Science and Art Center, which only children who pass the entrance exam can attend. The exam helps to identify gifted learners and organized by the Ministry of National Education. The school was equipped with a good internet connection and housed a science laboratory thereby enabling the convenient implementation of both types of laboratories. The science teacher involved, who taught both the control and experimental groups, had more than 10 years of experience in science teaching. There were 22 children in the control group, in which traditional hands-on experimentation was followed, and 21 in the experimental group, where the virtual laboratory environment was used. The students were distributed to the groups randomly.

Instruments

Two different data-gathering tools were used in the current study. These were a multiple-choice conceptual knowledge test and an inquiry skills test.

Multiple-Choice Conceptual Knowledge Test

This test consists of 20 multiple-choice questions developed by Deveci (2010) and revised by Özer (2019). Each question has four answer options. The questions on the test are about force, weight, velocity and motion. Each correct answer was given one point, so possible scores that can be reached change between 0 and 20. Cronbach's alpha coefficient was 0.73 for the conceptual knowledge posttest.

Inquiry Skills Test

The original version of the test is the Test of Integrated Process Skills (TIPS II) developed by Okey, Wise, and Burns (1982). It was translated into Turkish by Geban, Aşkar, and Özkan (1992). Aktamış (2007) revised the test for use with middle school pupils; this version was used in this study. The test includes 19 multiple-choice questions. Each question has four answer options. The test aims to measure learners' basic inquiry skills (e.g., observation, prediction, classifying) and higher-order inquiry skills (e.g., forming a hypothesis, designing experiments, determining or changing variables). Cronbach's alpha coefficient was 0.78 for the inquiry skills posttest.

Research Design and Implementation

The topic chosen was force and motion since the experiments in the unit were able to be done in both hands-on and virtual laboratories. Four different inquiry learning spaces were developed on the virtual platform by the researcher and the science teacher. Inquiry learning spaces are personalized learning resources for students, including a lab, apps and any other type of multimedia material. Laboratory worksheets, similar to the inquiry learning spaces, were also developed for the hands-on laboratory group. Pupils within each class were divided into two groups randomly. For those in the virtual laboratory environment, one class hour was organised to introduce the virtual learning environment. The tests were then administered as pre-tests. All pupils in the virtual laboratory environment were able to use computers individually. For the students in the hands-on laboratory environment, they were divided into groups where each had two students because of a lack of equipment. The students in the groups were randomly chosen. Both hands-on and virtual laboratory groups did the same experiments. The implementation process took three weeks. In the first week, the pre-test session and the first inquiry learning space (and its equivalent form for the hands-on group) were done. In the second week, two inquiry learning spaces and their equivalent forms for the hands-on group were used. In the third 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. The post-tests were implemented after a week of the implementation process.

Data Analysis

Because the data were not normally distributed and the limited number of participants in each group, we used the non-parametric Mann-Whitney U test to compare the pre-test and post-test scores. Furthermore, Wilcoxon Signed Rank test was used to compare each group's pre-test and post-test scores.

Results

Firstly, the results of the multiple-choice conceptual knowledge test were presented. And then, the findings based on the inquiry skills test were given. The multiple-choice conceptual knowledge test was implemented as both a pre-test and a post-test. Table 1 shows the descriptive results of the knowledge test.

Table 1

Average Scores for the Multiple-Choice Conceptual Knowledge

	Experimental Class (n=21) Mean (Sd)	Control Class (n=22) Mean (Sd)
Pretest	17.28 (2.79)	17.36 (2.06)
Posttest	19.05 (.92)	18.00 (1.72)
Difference	1.77 (2.72)	0.64 (1.18)

Pre-test scores revealed that the groups were similar to each other in terms of conceptual knowledge related to force and motion (U=214, p=.673). After the implementation process, the pre-test and post-test scores of each group were compared with the Wilcoxon Signed Rank test. The findings indicated that both of the groups enhanced their conceptual knowledge related to the topic throughout the study (Experimental Group, Z=-2.82, p=.005; Control Group, Z=-2.59, p=.010). Then, in order to reveal whether there is a statistically significant difference between the control and experimental groups' post-test scores, the Mann-Whitney U test was used again. The result showed that the difference in mean scores of the two groups is statistically meaningful (U=149.5, p=.040, d=0.86): the experimental group increased their score on the conceptual knowledge test significantly more than their counterpart.

The same procedure was followed for the inquiry skills test. Table 2 presents the descriptive data for the inquiry skills test.

Table 2

Average Scores for the Inquiry Skills Test

	Experimental Class (n=21) Mean (Sd)	Control Class (n=22) Mean (Sd)
Pretest	10.90 (4.12)	12.18 (3.17)
Posttest	16.19 (1.86)	13.63 (3.05)
Difference	5.29 (3.78)	1.45 (2.52)

Pupils in both groups had similar inquiry skills (U=194.5, p=.372) at the start . At the end of the study, it was revealed that both groups had improved their inquiry skills (Experimental Group, Z=-4.03, p=.000; Control Group, Z=-2.46, p=.014). Learners in the experimental group had improved their inquiry skills more than the ones in the control group (U=101.5, p=.001, d=1.01).

Discussion

In the current study, we investigated the effects of the use of virtual laboratories on gifted sixth-grade pupils' conceptual knowledge about force and motion, and their inquiry skills, when compared with gifted children who had been taught the topic in a hands-on laboratory environment. The results revealed that although both groups enhanced their conceptual knowledge and improved their inquiry skills throughout the study, the students in the experimental group attained significantly higher scores than their counterparts for both of the tests. This is consistent with studies in the literature that also show virtual laboratories can be effective in a learning process more than hands-on laboratories (Tüysüz, 2010).

This study was different in that the participants were gifted children. If they were in the hands-on laboratory environment, then they received guidance via the laboratory worksheet in written form; if they were in the virtual laboratory environment, they used online scaffolding tools in the same inquiry stages. Similarly, Eysink and colleagues (2015) concluded that gifted learners also need support during inquiry learning and if they are supported with proper guidance their potential may increase.

In terms of inquiry skills, all pupils improved their inquiry skills significantly, but those in the virtual laboratory environment showed better performance than their counterparts in the hands-on laboratory environment. This result may be due to the facilities provided by the virtual laboratory environments. Because the virtual laboratory environment provided online scaffolding tools such as hypothesis scratchpad and experiment design tool, such guidance can be more helpful for students in this laboratory environment. There are also some other studies in the related literature (e.g., Mutlu & Acar-Şeşen, 2016; Yang & Heh, 2007) that concluded that virtual laboratories are better environments to improve learners' inquiry skills than hands-on laboratory environments.

Virtual laboratories seem to work well with gifted learners. If they are supported to learn in technology-enhanced learning environments, their skills may increase. When the advantages of virtual laboratories are considered such as time and cost efficiency, converting invisible concepts into tangible forms, and they can be used to advantage for teaching gifted learners. This does not mean that hands-on laboratories should be abandoned. Hands-on laboratories have the advantage of developing pupils' psychomotor skills.

The science teacher will decide which type of laboratory environments s/he will use for her/his class(es). The teacher should be aware of the advantages and disadvantages of both types of laboratory environments. S/he should determine which objectives can be taught better in which laboratory. S/he also considers the facilities and physical conditions of her/his school.

Conclusion

In the current study, it was revealed that virtual laboratories are an appropriate instructional tool for gifted pupils. The ones in the virtual laboratory environment enhanced their conceptual knowledge and improved their inquiry skills better than the ones in the hands-on laboratory. But it is inadvisable to make certain conclusions just based on a single study. Further studies are needed. There are very few studies done with gifted learners using virtual laboratories, so similar studies should be done with different grades and with different topics. Gifted learners' views about virtual laboratories should be canvassed. The effectiveness of online scaffolding tools while used by gifted students can be investigated.

Both laboratory environments have their own advantages and drawbacks. A science teacher has a crucial role in deciding to use which type of laboratory environment.

Finally, the findings of the current study should be considered by taking the study's limitations into account. As mentioned above, although most of the students in the virtual laboratory environment used the computers individually mostly, students in the hands-on laboratory environment did the investigations in pair due to lack of equipment. Another limitation is that the same tests were used as pretest and posttest. We assumed that the number of the questions on the tests and the duration between the pretest and posttest hindered students to memorise the questions on the test.

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