# Evaluation of material supported virtual reality and animation on 6th grade students' success, cognitive levels and loads in the unit of circulatory system

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## Abstract

*The aim of this study was to research the effects of virtual reality and animation supported science teaching software prepared for 6th-grade systems in our body unit circulatory system subject on students' cognitive load levels, academic success and cognitive levels. Cognitive Level Scale (CLES) and Cognitive Load Scale (CLOS) were used as data collection instrument. When the results of the study were examined, a significant difference was found between cognitive levels of students in favour of the experimental group which received virtual reality software supported teaching. At the same time, since cognitive level scale is an achievement test, a comparison was made between the groups in terms of academic achievement. Academic achievements of the students in the virtual reality software supported experimental group were significantly different and higher when compared with students in the other group. In addition, when cognitive levels of the students were examined, it was found that virtual reality supported experimental group had higher cognitive levels when compared with other groups. When the scores of cognitive load scale were examined, it was found that virtual reality supported experimental group had lower cognitive load. As a conclusion, virtual reality supported science education contributes to students' academic achievement, their states of having higher cognitive levels and lower cognitive load.*

**Keywords**

*Animation, cognitive level, cognitive load, virtual reality*

**Résumé**

*L'objectif de cette étude était de rechercher les effets d'un logiciel d'enseignement des sciences soutenu par la réalité virtuelle et l'animation, préparé pour les systèmes de 6ème année de scolarité dans notre unité corporelle du système circulatoire, sur les niveaux de charge cognitive, la réussite scolaire et les niveaux cognitifs des élèves. Cognitive Level Scale (CLES) et Cognitive Load Scale (CLOS) ont été utilisés comme instrument de collecte de données. Lorsque les résultats de l'étude ont été examinés, une différence significative a été constatée entre les niveaux cognitifs des étudiants en faveur du groupe expérimental qui a reçu un enseignement soutenu par un logiciel de réalité virtuelle. En même temps, l'échelle de niveau cognitif étant un test de réussite, une comparaison a été faite entre les groupes en termes de réussite scolaire. Les résultats scolaires des étudiants du groupe expérimental soutenu par le logiciel de réalité virtuelle étaient significativement différents et supérieurs à ceux des étudiants de l'autre groupe. En plus, lorsque les niveaux cognitifs des étudiants ont été examinés, il a été constaté que le groupe expérimental soutenu par la réalité virtuelle avait des niveaux cognitifs plus élevés par rapport aux autres groupes. Lorsque les scores de l'échelle de charge cognitive ont été examinés, il a été constaté que le groupe expérimental soutenu par la réalité virtuelle avait une charge cognitive plus faible. En conclusion, l'enseignement des sciences soutenu par la réalité virtuelle contribue à la réussite scolaire des étudiants, à l'augmentation de leurs niveaux cognitifs et à la diminution de leur charge cognitive.*

**Mots-Clés**

*Animation, niveau cognitif, charge cognitive, réalité virtuelle*

## Introduction

Along with the changing and developing technology, today's societies are experiencing a rapid change and countries have to keep up with this rapid change. Adapting to the developing and changing world from all aspects is an inevitable fact. For this reason, there have been changes in needs and requirements. Education and training activities have an important place in meeting these needs. For this reason, education has started new searches for its changing needs. Education has undergone radical and great changes from the past to the present. An increase is seen in success in other areas as a result of the innovations in education (Scott & Marshall, 2009). Therefore, it is possible to mention a continuous increase in the field of education. Countries want their people to access information simultaneously and as quickly as possible (Huzvar & Rigova, 2016). Technology makes great contributions to responding to changing expectations, especially considering the century that we are living in. It is thought that it will be effective in the development and acquisition of various skills (Chen, 2017). With the developing technology, the need for individuals who can effectively use the steps of scientific process, who have advanced thinking skills and who are technology-literate, has increased in the society (Huang, Rauch, & Liaw, 2010; Nordlöf, Höst, & Hallström, 2017). For this reason, it is important to acquire 21$^{st}$ century skills in terms of personal development. In today's conditions, 21$^{st}$ century skills and interdisciplinary studies are in intense interaction with technology (Çepni & Ormancı, 2017).

Technology is very important in terms of storing, structuring, reproducing, and sharing information (Aktamış, 2017). Due to the nature of these skills, the prevalence and importance of science technology and technological equipment has increased even more (Liou, 2018). More permanent and effective learning can be possible through various visual and auditory stimuli. Individuals are more willing in activities involving technology (Trilling & Fadel, 2009). The most common and known a wide range of tool of technology in education is "Information and Communication Technology (ICT)".

ICT technologies contribute to the storage and processing of information after gathering and transferring and accessing information when needed. (Işık & Akbolat, 2010). ICT has all of the technological tools which enable information to be collected, created and accessed from various resources (Çavas, Kışla, & Twinning, 2004). It enables individuals to acquire and develop 21$^{st}$ century skills. ICT plays a role in the assessment and restructuring of information, transfer to other individuals and in the development of critical thinking skills (Manunure, Delserieys, & Castéra, 2019). Today, rapid developments in ICT are among structures that make the greatest contribution to solve problems. In addition to traditional methods and techniques, it can evaluate many problems from different aspects and find various solutions (Cukurova, Bennett, & Abrahams, 2018). ICT shows a great success in teaching three dimensional structures, which are complicated and extremely difficult to understand (Liou, 2015). Thanks to ICT, people can reach the information they want in different environments and under many conditions. Due to the modern structure of the activities carried out with education and ICT integration and the creation of innovative and effective learning environment, the interest and advancements in this field continue to increase (Güneş, Yüksel, & Kaya, 2017). At the center of this progress is that ICT includes many disciplines and has a great significance in terms of its functions in our lives. Direct integration of ICT in learning environments will help the development of more effective educational activities.

As in other fields of education, ICT is inherently closely associated with science education (Aktamış, 2017). Science education attaches importance to the structuring of information by students (Guzey, Harwell, & Moore, 2014). The aim of science education is to enable individuals to learn by doing and to examining the nature and the environment (Goodwin, Wiltshire, & Fiore, 2015). Science education takes place both outside of school and in the laboratory environment. One of the difficulties encountered from time to time is limited access to these environments. For this reason, students are presented the necessary environments through software and hardware elements. The information that students are being structured by themselves provides more efficient and meaningful learning (Özen, Yazıcıoğlu, & Çınar, 2017). When compared with traditional teaching tools, ICT supported science education provides important opportunities to increase students' success. At the same time, it is positively affected by technological developments and includes many innovations. Differences are shaped in ICT with virtual content and other different educational environment (Liou, 2015). Especially since the beginning of this century, software and hardware which have higher quality and efficiency each day are being included more effectively in many parts of our lives (Duncan, Miller, & Jiang, 2012). Especially virtual reality attracts attention recently in the field of software and its use in different areas has become more and more common (Coruh, 2011). Virtual reality (VR) provides an environment created in the minds of individuals and perceived as real with 3D visual and auditory content prepared in computer along with auxiliary technological tools and software (Bowman & Mcmahan, 2007). An empty digital can be considered as the space (Gregory et al., 2016). The content created allows individuals to interact with objects, the environment, and also other people with the help of equipment (Yıldırım & Selvi, 2017). Restructuring of information allows individuals to recreate information and interact more (Merchant et al., 2014). Virtual reality is based on the restructuring and reshaping of the real world in virtual environment with the help of technological devices and software (Aslan, 2017).

Virtual reality began to be used in the middle of 20$^{th}$ century for the first time. It was first used for military purposes. It was later used in medicine, space exploration and many areas. Virtual reality software has been developing rapidly since the beginning of 21$^{st}$ century. Virtual reality software, the application area of which is developing day by day, has also started to be effective in education (Gregory et al., 2016). It has brought a new perspective in the field of education by using the hardware structures it has (Bowman & McMahan, 2007). It has become more important with the speed of new technological developments. Virtual reality software, which was difficult to reach at the first stage, is more widely used today. Virtual reality software, which has rich virtual and auditory rich content, enable the individual to interact with the virtual environment. It offers an experience of feeling more when compared with other two-dimensional and three-dimensional visuals (Johnston et al., 2018). Transferring abstract and difficult to reach concepts and subjects to the virtual environment is one of the places which are used the most in science education.

Virtual reality creates physical spaces in the form of simulation and also gives a sense of reality (Luo & Wu, 2022). Virtual reality not only affects visual richness but also the perception of reality affects people psychologically (Abidi, Al-Ahmari, & Ahmad, 2018). It is presented on a 3D remote display surface in the animation environment. However, in virtual reality, individuals find themselves directly in 3D space. Therefore, the sense of reality is among the most prominent features of VR applications (Gregory et al., 2016). However, VR is utterly effective in communicating with the world, increasing social communication, and sharing (Zhang, Wei, & Xu, 2020). VR allows students to explore new areas, make predictions, make choices, and design experiments. It helps students to achieve specific goals by providing motivation. Studies have shown that students have a positive attitude towards the use of VR in education (Pantelidis, 2010). VR contributes to attracting and keeping students' attention on the subject (Freina & Ott, 2015). Students state that they are excited to be in a 3D virtual environment (Hu-Au & Lee, 2017). VR allows examining in a 3D detail in the 3D environment. For example, when a model and structure is given to students, it allows them to analyze in detail from every aspect (Pantelidis, 2010). VR encourages active participation and communication by bringing different perspectives to the way students connect and relate to the subject. Unlike other 2D animation applications, it offers a high level of interaction. The intense relationships between studied structure, and the real world contribute to the understanding of the models and the subject (Abidi et al., 2018). Students also learn in line with their learning speed can be shown as another advantage of VR applications (Pantelidis, 2010). VR learning takes place based on constructivist learning theory (Carruth, 2017). In addition, software, cost, hardware, and usage are shown as negative aspects of VR applications (Pantelidis, 2010). The solution of the problems at the point of application in all schools is directly related to the developments in technology (Chen, 2010).

The features of virtual reality software coincide with the nature of science education. In science courses where there is too much abstract and complicated context, students often have difficulty in meaningful and permanent learning (Owens & Hite, 2020). Old Software becomes inadequate over time in terms of understanding and comprehending knowledge. Unlike old and outdated educational software, virtual reality software contributes to individuals' abstract thinking skills and reaching information by themselves (Bayraktar & Kaleli, 2007). Virtual reality software helps individuals to develop cognitively when compared with old approaches (Mikropoulos & Natsis, 2011). Its interesting and intriguing structure increase motivation and interest in education (Arıcı, 2013). Educational software based on virtual reality helps students to develop their senses and mental development with their visual and auditory richness (Çavaş et al., 2004). Virtual reality software is compatible with Constructivist Approach, which has an important place in science education. The aim is to educate students who can question cognitively, think critically, who have high problem-solving skills and who are creative with the help of such software. Having these skills enables students to have a high cognitive level (Gardner, Demirtaş, & Doğanay, 1997).

Constructivist approach is based on the interpretation of knowledge by students. Thanks to a student-centred system, many skills of students are improved. Many developed software and hardware items provide students with insufficient opportunities for the development of these skills. Students generally remain in cognitive levels such as knowledge and comprehension in learning information. Instead, students are expected to have higher cognitive levels (Aydın, 2015). When the existing science curriculum is examined, it can be seen that it is based on inquiry-based teaching (MEB, 2018). Different approaches (argumentation, etc) are predicted for students in achieving this goal. When it comes to the basis of these, it is seen that the effective use of the constructivist approach, which previously dominated the curriculum, still has a significant role in students' reaching the desired goals.

One of the basic principles of constructive learning theory is to know the previous subjects and concepts well, especially in the permanent and meaningful learning of new concepts (Fosnot & Perry, 1996). Students remember their previous knowledge and combine it with new knowledge through flow of information between the memories. Different types of memory work in the brain while learning activities are taking place in the human mind. At this point, there is short-term memory, which we call working memory. Short term memory is the type of memory used while learning information. Each new information that students learn during learning activities is primarily stored in short-term memory. In this part, the processed and symbolized information is then transferred to the long-term memory.

It is desired to transfer information to long-term memory without letting it remain too much in the short-term memory. The information contained in short-term memory consists of information we obtain in our daily school life or outside (Sweller, Van Merrienboer, & Pass, 1998). This information must be transferred to long-term memory so that it can be used and also for learning to take place (Schnotz & Kürschner, 2007). The information transferred to long-term memory turns into more permanent and more efficiently used information set. It is desired that information does not stay too long in short-term memory; on the contrary, it should be transferred to long-term memory (Takır, 2011). Long term memory provides the opportunity to reach information and schemes very easily. This way, the rapid transfer of information from short-term memory to long-term memory reduces the exposure of students to overdensity or load in students' short-term memory. The intensity and overload in short-term memory cause students' learning processes to be incomplete (Kaya, 2015). As a result of this, the information learned stays in short-term memory and cannot be used later. For this reason, this situation should be paid attention to in learning activities (Kablan & Erden, 2008). Course contents and the materials used should be used in accordance with his situation. Otherwise, short-term memory becomes loaded and efficient learning cannot be achieved (Sweller et al., 1998).

Cognitive load is defined as the load that occurs while the information in students' short-term memory is processed and transferred to long-term memory during learning activities (Şişman & Küçük, 2018). In its nature, cognitive load theory aims to transfer the information in short-term memory to long-term memory rapidly.

For faster transfer of information in short-term memory to long-term memory, materials suitable for cognitive load theory are used (Çoban, 2020). Cognitive load theory hinders students from being loaded with excessive cognitive load and enables information to be remembered and to be transferred to long-term memory. It is stated that learning should be kept away from situations that complicate the course and affect information and focus. According to the cognitive load theory, it is thought that the visual and auditory materials prepared can prevent excessive cognitive load. Thus, it is expected for students to transfer information from short-term memory to long-term memory faster (Kaya, 2015). In case of excessive cognitive load, the intensity in short-term memory causes students to encounter problems in making sense of information and transferring it to long-term memory (Sweller, 2006).

To be able to overcome these basic problems mentioned above, development of a virtual reality based guiding material for Systems in Our Body unit of 6th grade constitutes the basis of the present study. Students are asked to visualize the concepts in their minds and learn three dimensional structures. At the same time, the aim is not to cause students to be overloaded with cognitive load and to transfer information to long-term memory (Sweller, 2006). When the literature is reviewed, no studies were found which examined the effects of virtual reality supported educational facilities in circulatory system on students' cognitive level and cognitive load.

The main purpose of the present study was to examine the effects of virtual reality supported science education software prepared for 6th grade Systems in our Body unit, Circulatory System topic on students' cognitive load levels, academic achievement, cognitive levels. In line with this purpose, answers will be sought to the following research questions:

1. What are the effects of virtual reality and animation supported applications on students' cognitive levels?
2. What are the effects of virtual reality and animation supported applications on students' academic achievement?
3. What are the effects of virtual reality and animation supported applications on students' cognitive load?

## Method

In this study, one of the experimental research methods - quasi-experiment method was used. The aim of survey model is to assess a situation by showing the situation that a group has (Table 1). These situations can be the students' views or attitudes. The findings of survey model are expressed numerically (Çepni, 2014). Thus, the researcher can make a generalization about the study group with the help of the results obtained. The aim is to show the differences of groups which are the subjects of the study.

**Table 1**

*Symbolic view of the experimental model*

| Groups | Pre-test | Practice | *Post*-test |
|---|---|---|---|
| **E1 (Virtual Reality Supported Experimental Group)** | P1 | Ministry of Education Curriculum + X1 | P2 |
| **E2 (Animation Supported Experimental Group)** | P1 | Ministry of Education Curriculum + X2 | P2 |
| **C1 (Control Group)** | P1 | Ministry of Education Curriculum | P2 |

*X1: Virtual reality supported applications, X2: Animation supported applications, P1: Pre-measurements of experimental groups and control groups, P2: Pre-measurements of experimental groups and control groups*

### Research process

The research process was carried out with the following process steps. The study was carried out in 12-course hours, 4 hours per week for 3 weeks. The students applied the virtual reality applications twice, in groups of 6-7 people. The students applied the VR application related to the relevant circulatory system twice for each subject. First, virtual reality material was developed. At the same time, animation practices to be used in the other experimental group were determined. Pilot study was carried out with teacher and students. The materials and the data collection tools used were finalized by taking into consideration the feedbacks of the pilot study and the opinions of experts in the field, science teacher and experts studying in the field of technology assisted science education. Along the research process, lessons are conducted by the same teacher in all groups.

Virtual reality material and animation were introduced to teacher before the experimental process. Teacher were requested to ask detailed questions about the use. Particularly in the experimental process, it has been dwelled on at the point of transferring the necessary information to help the students' questions for teachers.

Finally, they were made ready for teachers' use. Materials were introduced to students before the experiment. Students' questions about how they would use the materials and the applications were answered.

The researchers were introduced to the students. If needed, we ensured that they followed the process at a suitable point in the classroom.

**TABLE 2**

*Student attainments from the circulatory system*

| Students' gain |
|---|
| Explain the functions of the structures and organs that make up the circulatory system by using the model. |
| Students explain the big and small blood circulation on the scheme and explain their duties. |
| Defines the structure and duties of the blood. |
| Refers to blood exchange between blood groups. |
| Evaluates the importance of blood donation for society. |

Can explain the functions of the structures and organs that make up the circulatory system by using model. Can analyse the large and small blood circulation on a diagram and explain the functions of these. Can describe the structure and functions of blood. Can express the exchange of blood between blood groups. Can evaluate the importance of blood donation in terms of the society. The attainments that make up the subject are mainly based on showing structures and organs on models and explaining their functions (Table 2). Virtual reality material and animation application are used when teachers need to show structures and organs on models while teaching the course. Different groups of students examined structures such as heart, blood vessels, lung and liver from virtual reality material, animation applications and anatomical human skeleton in the classroom. Similarly, different groups of students examined small and large blood circulation with virtual reality material, animation applications and two dimensional poster in the classroom. After the attainments in the circulatory system unit were finished, cognitive level scale and cognitive load scales were applied to the students in groups. The pictures of the application process are below (see Figure 1, 2). At the same time, the road map of the research process is also shown in Figure 3.

**FIGURE 1**

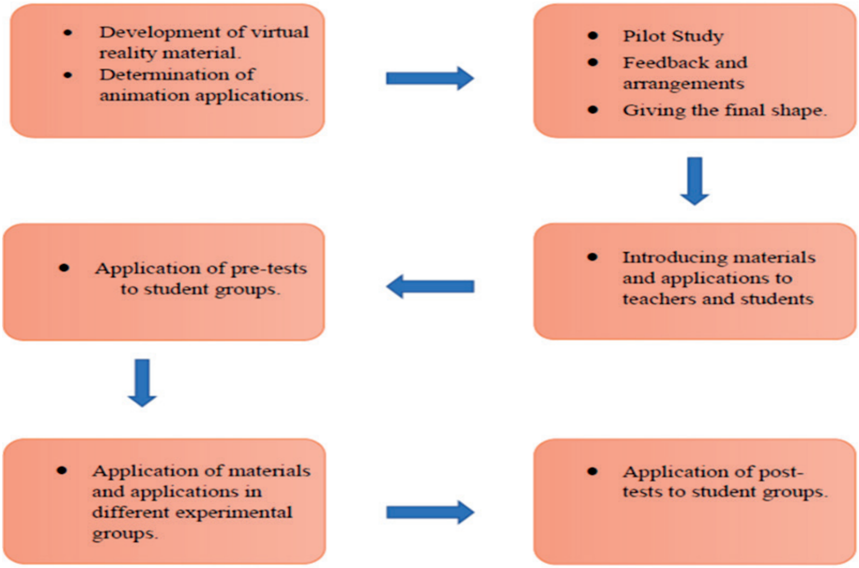
*Virtual reality material application process in the first experimental group*

**FIGURE 2**

*Animation material application process in the second experimental process*

In the virtual reality-supported experimental group, the lessons are carried out based on the virtual reality course material and the national curriculum. In the animation-supported experimental group, the lessons are carried out based on animation applications and the national curriculum. In the control group, the lessons are carried out based on the national curriculum. The mutual features of the groups are stated as the information and practices in the coursebook and curriculum. The different points of the groups are; VR applications for the virtual reality supported-experimental group and animation applications for the experimental group with animation lessons.

**FIGURE 3**




*Steps of the research process*

## Study group

The population of the study consists of all 6 th graders in a state school of Altınordu town in Ordu. The sample of the study was selected with simple random selection method, which is one of the probability sampling methods. The sample of the study consists of all 108 students in a state school of Altınordu town in Ordu during the 2018-2019 academic year. There were 36 (male=19, female=17) students in the virtual reality supported experimental group, while there were 36 (male=17, female=19) students in animation supported experimental group and 36 (male=22, female=14) students in the control group.

Students are in an intermediate socio-economically school. In addition, the circulatory system profiles of the students will be determined and decided after the pre-tests. It is aimed to reveal the level of the groups at the beginning with the result of the tests. It is aimed to investigate the effectiveness of the experiment process comparing the measurements after and before the experiment.

## Development of Virtual Reality material

The circulatory system consists of three dimensions as structure, organ, and functions. When the literature is reviewed, problems are experienced in showing structure, organs and small-large body circulation on the model (Karamustafaoğlu, Pazar, & Karamustafaoğlu, 2018). In addition, students have difficulties in understanding concepts and making associations and thus cause misconceptions (Pelaez et al., 2005). For this reason, the material planned to be developed should be prepared by considering the situations specified. The VR application is specifically aimed to design to increase the academic success of students, improve their cognitive levels and at the same time reduce their cognitive load.

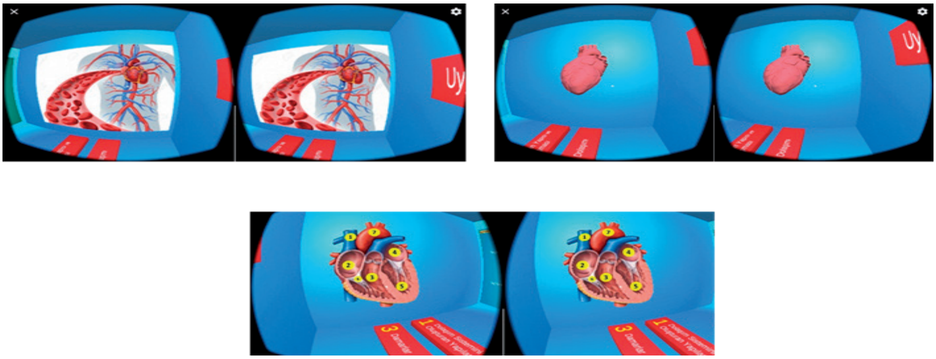
Virtual reality material has been prepared by using unity software. Unity is very easy to use and has an understandable interface. It is also used in different studies in the field of education (Senio, 2021).

During the development phase, cognitive load principles are primarily taken as the basis during the process of development. Cognitive load centred materials aim to prevent students' excessive cognitive load (Kaya, 2015). Thus, students get the opportunity to transfer the information to long-term memory by processing the knowledge. The opinions of science teachers and experts in the field were taken while preparing virtual reality supported material for circulatory system unit. Teachers are in direct observation of the problems encountered in the lessons. Therefore, teachers' views on the process, especially on the use of VR applications, are essential. Teachers often repeat that the interface of the application should not be too complicated. Besides, the appropriateness of the visuals for age groups is another dimension mentioned.

First of all, the scenes planned to be prepared were decided by considering attainments. Attainments and goals in the teaching program were taken into consideration in the determination of scenes (see Table 3).

It is a known fact that students have problems while thinking about circulatory system and its structures three dimensionally (Agad et al., 2019; Kumalasari, Hilmi, & Priyandoko, 2017). Pulmonary circulation and systemic circulation can be shown as examples of concepts that students have difficulty with (Kim et al., 2020). The frequent presence of abstract structures makes it difficult for students to understand the circulatory system (Agad et al., 2019). For this reason, staging of circulatory system structures and organs is of great importance. In the second part, the scenes were designed with educators in the field in addition to experts in cognitive load and virtual reality. In the preparation of the scenes, first of all the scenes were prepared as two-dimensionally. Next, virtual reality scenes were formed with the help of unity by experts in the field of virtual reality, science educators, individuals who were experts in the field and individuals working in the field of cognitive load. The material prepared was first of all tested with pilot application. With the changes in scenes as a result of feedback from students, experts in the field and science educators, the material was made ready for the application process. Some of the scenes of the developed material are presented below (see Figure 4). BOBO VRZ 4 model was used as VR tool.

**FIGURE 4**



*Virtual reality material sample scenes*

The fact that any of the students did not use glasses due to their visual impairment during VR applications did not cause any problems. Otherwise, the students were excluded from the study due to the possibility of dizziness. As a result, no dizziness problem has been encountered during VR applications. Considering that the students are 12 years old, the applications were carried out under the supervision of teachers and researchers.

Students have the opportunity to explore the structure of the heart in the VR application. It makes it possible for them to pass between the structures and organs that form the circulatory system. In this way, students can see the abstract concepts they encounter in a 3D environment.

## Determination of animation applications

There are similarities and differences between animation and VR applications. Especially for abstract concepts, both teaching methods have a substantial place (Li, Zhu, & Hu, 2021).

Animation applications were carried out in animation supported experimental group. First of all, existing materials which were suitable for circulatory system and grade level were researched. A selection was made among free animations which did not contain copyright. The animations used in the experimental group with animation support were determined as 2D and 3D. The attainments in the curriculum were also taken into consideration while choosing animations. Secondly, the animations determined were examined by experts in the field, experts conducting studies in the field of technology supported science education and science teachers. Animations determined during the process of pilot application were used. The animations were made ready for the application process as a result of the feedback taken from students, field experts and science teachers. Animations were watched more than once during the course in accordance with the curriculum.

## Data Collection Instruments

Cognitive Level Scale (CLES) was developed by the researcher to determine the cognitive levels of students and to examine their academic achievement scores. Cognitive load scale (CLOS) was used to measure the cognitive load levels students showed during the study.

Cognitive Level Scale (CLES): Bloom divides cognitive states into different levels. Students with higher cognitive levels have particular skills (Çepni, Taş, & Köse, 2006). It was used to determine the cognitive levels of students and to show their cognitive level. The scores from CLES were also used to determine the students' academic achievement. During the development process of CLES, first of all features of cognitive levels were examined in detail. In particular, examining Bloom's cognitive theory is critical at this point (Çepni et al., 2006).

Next, a large number of sixth grade books were examined. The main reason for examining the textbooks is to have an idea for the preparation of questions by the cognitive level.

The first version of the scale was developed by considering the unit outcomes in accordance with the renewed curriculum. In order to find out whether the developed scale had content validity and whether it included a scientific mistake, four science teachers and three experts in the field were consulted. The scale was finalized as a result of the feedback taken from experts in the field and made ready for pilot application. During the pilot application, the initial version of the scale which included 40 questions was reduced to 28 questions and it was finalized. The pilot study was conducted on 132 students studying in a state school of Ordu Altınordu. As a result, to the application, it was found that the items in the scale were not distributed homogeneously. For this reason, the reliability of the scale and its results were calculated by using KR-20 formula. As a result of the analyses conducted for the scales, KR-20 internal consistency coefficient was calculated as 0.83. The numbers of questions included in the cognitive levels that make up the scale are given in Table 3.

**TABLE 3**

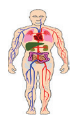
*Distribution of the questions of CLES cognitive level*

| Cognitive Level Step | Number of questions |
|---|---|
| Information | 8 |
| Comprehension | 5 |
| Application | 4 |
| Analysis | 4 |
| Synthesis | 2 |
| Evaluation | 5 |

The numbers of items in CLES were distributed heterogeneously to cognitive levels. The reason for this is the fact that items are excluded from the item pool in order to increase the reliability of the scale. Another reason for the heterogeneous distribution is the creation of item pool by taking the attainments and suitable cognitive level into consideration.

**TABLE 4**

*Cognitive level scale sample questions*

| Cognitive Level Step | Questions |
|---|---|
| **Information** | • What are the structures and organs involved in the circulatory system? |
| | • Which of the following is not a blood cell?<br>• A.White blood cells B. Red blood cells C. Blood flakes D. Plasma |
| **Comprehension** | • The structures and the organs which make up the circulatory system can be likened to…..? |
| | • The veins which take blood to the heart are called …………………I………………………., while the veins which carry the blood from our heart to the different areas of our brain are called …………………II………………………. Fill in the gaps numbered I and II in the most suitable way |
| **Application** | • What around us can be likened to the blood in our body? |
| **Analysis** | • Ayşe wants to find out which structures and organs have a role in the circulatory system by looking at the picture. Which of the following would be correct?<br><br>• A.Nose, air, heart<br>• B.Blood, lungs, veins<br>• C.Air, lungs, small intestine<br>• D. Blood, heart, veins |
| **Synthesis** | • Except for the pulmonary artery, the other arteries carry oxygenated (clean) blood. Except for the pulmonary vein, the other veins carry oxygen-poor (dirty) blood. What can be the reason for this? |
| **Evaluation** | • Explain the importance of the structures and organs in the circulatory system |

It is aimed to have an idea about the cognitive level scale by instantiating from different types of questions. Different types of questions in the scale contribute to revealing the cognitive levels of students (Sobral, 2021).

Cognitive Load Scale: Cognitive load scale was used to measure the cognitive load levels of students during the study period. Cognitive load scale developed by Pass and Van Merrienboer (1993) was used. The scale was adapted by Kılıç and Karadeniz (2004) and the required permissions were taken. Required permissions were taken by Kaya (2015) who revised and used the scale. A large number of validity and reliability studies have been conducted for the scale. In Sezgin's (2009) study, Cronbach Alpha internal consistency coefficient of the scale was found as 0.78. The scale has 10 concepts.

These concepts consist of circulatory system subjects. In order, heart, blood, veins, systemic circulation, microcirculation, lung, arteries, veins, capillaries, blood groups, and all (general comment for all questions). The students are asked questions about the learning process of these 10 concepts during the course. The students are asked to grade the difficulty they experience while learning the concepts. Students' concepts were graded from "very little" to "very much" in 9 levels, respectively.

### Data Analysis

The data obtained during the research process were analyzed with various analysis methods. Quantitative data were analyzed with SPSS 22 program. Descriptive analysis of the data was made with item mean, standard deviation and percentages. In the light of the data taken from CLES, descriptive analyses were conducted separately for each level and each group. Shapiro-Wilk normality test was conducted to find out whether the cognitive load scale data taken from the students were normally distributed. Level of significance was taken as ($p \leq 0.05$). The analyses were made with Independent Samples one-way ANOVA since three groups were compared or with non-parametric Kruskal Wallis when the data were not normally distributed.

## Findings

In this part of the study, the data obtained in the study were analyzed with the help of analysis methods and presented in tables.

Pre-test cognitive levels of the students in the experimental group taught with virtual reality software, the students in the experimental group taught with animation supported learning method and the students in the control group taught with only science education program were analyzed with descriptive statistical analysis method. Descriptive analysis consists of mean score, standard deviation, and percentage values. Cognitive Level Scale consists of six different cognitive levels. The scores the students got from each level were evaluated within each level. The maximum score students can get from each level is 100%. Table 5 shows descriptive analysis results of pre-test cognitive levels of the groups.

**TABLE 5**

*CLES pre-test descriptive analysis results of the groups*

| | Control Group | | | Animation Supported Experimental Group | | | Virtual Reality Supported Experimental Group | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}$ | SS | % | $\bar{X}$ | SS | % | $\bar{X}$ | SS | % |
| **Information** | 2.888 | 1.213 | 36.11 | 3.088 | 0.995 | 38.60 | 2.305 | 0.920 | 28.82 |
| **Comprehension** | 1.972 | 0.940 | 39.44 | 2.058 | 1.126 | 41.17 | 1.777 | 1.072 | 35.56 |
| **Application** | 1.916 | 0.967 | 47.91 | 1.970 | 0.797 | 49.26 | 1.861 | 0.899 | 46.52 |
| **Analysis** | 1.583 | 0.996 | 39.58 | 1.911 | 0.792 | 47.79 | 1.583 | 0.806 | 39.58 |
| **Synthesis** | 0.166 | 0.377 | 8.335 | 0.323 | 0.474 | 16.17 | 0.305 | 0.467 | 15.2 |
| **Evaluation** | 0.805 | 0.888 | 16.11 | 1.147 | 0.892 | 22.94 | 0.833 | 0.810 | 16.6 |

When Table 5 is examined, it shows the mean, standard deviation and percentage values of each step that constitutes the cognitive levels of groups. In control group, the percentage of correct answers to information step is 36.111%, while it is 39.144% for comprehension step, 47.917% for application step, 39.582% for analysis step, 8.335% for synthesis step and 16.112% for evaluation step. In animation supported experimental group, the percentage of correct answers to information step is 38.602%, while it is 41.176% for comprehension step, 49.265% for application step, 47.795% for analysis step, 16.175% for synthesis step and 22.942% for evaluation step. In virtual reality supported experimental group, the percentage of correct answers to information step is 28.82%, while it is 35.56% for comprehension step, 46.527% for application step, 39.582% for analysis step, 15.28% for synthesis step and 16.66% for evaluation step. Table 6 shows descriptive analysis results of post-test cognitive levels of the groups.

When Table 6 is examined, it shows the mean, standard deviation and percentage values of each step that constitutes the cognitive levels of groups. In control group, the percentage of correct answers to information step is 58.985%, while it is 53.126% for comprehension step, 61.72% for application step, 61.72% for analysis step, 18.75% for synthesis step and 18.75% for evaluation step. In animation supported experimental group, the percentage of correct answers to information step is 67.50%, while it is 67.50% for comprehension step, 55.00% for application step, 66.4275% for analysis step, 27.415% for synthesis step and 34.508% for evaluation step. In virtual reality supported experimental group, the percentage of correct answers to information step is 68.2125%, while it is 65.714% for comprehension step, 65.714% for application step, 65.714% for analysis step, 57.145% for synthesis step and 64.572 % for evaluation step.

**TABLE 6**

*CLES post-test descriptive analysis results of the groups*

| | Control Group | | | Animation Supported Experimental Group | | | Virtual Reality Supported Experimental Group | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}$ | SS | % | $\bar{X}$ | SS | % | $\bar{X}$ | SS | % |
| **Information** | 4.718 | 2.173 | 58.98 | 5.400 | 1.555 | 67.50 | 5.457 | 1.521 | 68.21 |
| **Comprehension** | 2.656 | 1.035 | 53.12 | 2.857 | 1.004 | 57.41 | 3.285 | 1.126 | 65.71 |
| **Application** | 2.468 | 1.046 | 61.72 | 2.200 | 1.023 | 55.00 | 2.600 | 0.945 | 65.00 |
| **Analysis** | 2.468 | 1.106 | 61.72 | 2.657 | 0.998 | 66.42 | 2.400 | 0.913 | 60.00 |
| **Synthesis** | 0.375 | 0.553 | 18.75 | 0.542 | 0.700 | 27.41 | 1.142 | 0.772 | 57.14 |
| **Evaluation** | 1.781 | 1.288 | 35.62 | 1.571 | 1.289 | 34.50 | 3.228 | 1.436 | 64.57 |

In the study, it was tested whether there were significant differences between pre-test and post-test cognitive level scale academic achievement scores of experimental group students taught with virtual reality software supported teaching, experimental group students taught with animation supported teaching method and control group students taught with only science education curriculum. Normality test was conducted to find out whether the data were distributed normally (Table 7).

**TABLE 7**

*CLES pre/post-test normality test results*

| | Groups | Kolmogorov–Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|---|
| | | Statistic | df | Sig.(p) | Statistic | df | Sig. (p) |
| **CLES Pre-Test** | Virtual Reality Supported Experimental Group | .182 | 36 | .04 | .956 | 36 | .163 |
| | Animation Supported Experimental Group | .159 | 36 | .03 | .965 | 36 | .297 |
| | Control Group | .126 | 36 | .160 | .950 | 36 | .105 |
| **CLES Post-Test** | Virtual Reality Supported Experimental Group | .134 | 36 | .115 | 0.963 | 36 | 0.273 |
| | Animation Supported Experimental Group | .149 | 36 | .149 | 0.964 | 36 | 0.285 |
| | Control Group | .090 | 36 | .200 | 0.965 | 36 | 0.304 |

Since the data obtained from CLES were normally distributed, one-way ANOVA was applied to the data obtained. The results obtained are shown in Table 8.

**TABLE 8**

*CLES pre/post-test academic achievement scores independent samples one-way ANOVA results of the groups*

| | Source of Variance | Sum of Squares | df | Mean Squares | F | Sig. (p) | Significant Difference (Scheffe) | Effect Size |
|---|---|---|---|---|---|---|---|---|
| **CLES Pre Test** | Between Groups | 18.963 | 2 | 9.481 | 1.035 | 0.359 | | 0.01932 |
| | Within Groups | 962.222 | 105 | 9.164 | | | | |
| | Total | 981.185 | 107 | | | | | |
| **CLES Post Test** | Between Groups | 354.130 | 2 | 177.065 | 9.352 | 0.000 | E1-E2<br>E1-C1 | 0.14955 |
| | Within Groups | 2013.70 | 105 | 19.179 | | | | |
| | Total | 2367.80 | 107 | | | | | |

The cognitive levels of the groups were examined with the analysis. Thus, it was aimed to reveal the change in cognitive levels before and after the experiment when Table 9 is examined, no significant difference is seen between CLES pre-test scores. However, significant difference was found between CLES post-test scores ($p<0.05$, $p=0.00$). To find out which groups the difference was in favour of, post hoc test Scheffe was made since the variances were homogeneous. Statistically significant difference was found between the control group and virtual reality supported experimental group ($p<0.05$). This difference was in favour of virtual reality supported experimental group. No statistically significant difference was found between the control group and animation supported experimental group ($p>0.05$). No statistically significant difference was found between animation supported experimental group and virtual reality supported experimental group ($p<0.05$). This difference was in favour of virtual reality supported experimental group. At the same time, effect size eta square value was calculated. eta square value was calculated as 0,01932 for CLES pre-test and as 0,14955 for post-test.

In the study, it was tested whether there were significant differences between pre-test and post-test cognitive load scale scores of experimental group students taught with virtual reality software supported teaching, experimental group students taught with animation supported teaching method and control group students taught with only science education curriculum. Normality test was conducted to find out whether the data were distributed normally (Table 9).

**TABLE 9**

*CLOS normality test results*

| | Groups | Kolmogorov–Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|---|
| | | Statistic | df | Sig. (p) | Statistic | df | Sig. (p) |
| CLOS | Virtual Reality Supported Experimental Group | .286 | 36 | .00 | .86 | 36 | .00 |
| | Animation Supported Experimental Group | .264 | 36 | .00 | .865 | 36 | .00 |
| | Control Group | .262 | 36 | .00 | .876 | 36 | .01 |

Descriptive analysis and Kruskal Wallis test were conducted on the data obtained since the scores from CLOS were not normally distributed for all groups. Tables of the results are shown below.

**TABLE 10**

*CLOS Descriptive analysis results of control and experimental groups*

| Groups | N | $\bar{X}$ | Ss |
|---|---|---|---|
| Control Group | 36 | 5.3611 | 0.93052 |
| Animation Supported Experimental Group | 36 | 5.1359 | 0.7983 |
| Virtual Reality Supported Experimental Group | 36 | 4.5833 | 1.1051 |

As can be seen in Table 10, mean scores are ($\bar{x}$=5.3611) for the control group, ($\bar{x}$= 5.1359) for the animation supported experimental group and ($\bar{x}$=4.5833) for the virtual reality supported experimental group. Table 11 shows Kruskal Wallis results of cognitive load of the groups.

According to the results of the Kruskal Wallis analysis, significant result was found between the cognitive load scale scores of control and experimental groups ($p<0.05$, $p=0.006$, $X^2=10.349$). Cognitive load scale scores of virtual reality supported experimental group students were found to be lower. This result shows that experimental group students showed less effort when compared with the other groups while learning the subject. However, this difference between the groups was found to be statistically significant.

**Table 11**

*Kruskal Wallis results of CLOS scores of control and experimental groups*

| Groups | N | Mean Rank | SD | X2 | p | Significant Difference |
|---|---|---|---|---|---|---|
| **Control Group** | 36 | 61.65 | 2 | 10.349 | 0.006 | |
| **Animation Supported Experimental Group** | 36 | 57.50 | | | | D1-D2<br>D1-D3 |
| **Virtual Reality Supported Experimental Group** | 36 | 42.35 | | | | |

## Discussion and conclusion

The result that there is no difference between the groups in the pre-test indicates a positive situation in terms of reflecting the effect of the method to be applied on the groups. The effect size calculated between the groups is defined as a low effect ($\eta 2=0.14955$; see Table 9)

In post-test academic achievement scores taken from CLES, significant difference was found between the control and experimental groups in favour of the virtual reality supported experimental group ($p<.05$; see Table 9). The difference between animation supported experimental group and the control group was not found to be significant. However, difference was found between the academic achievement scores of both groups. The effect size calculated between the groups is defined as large effect ($\eta 2=0.14955$; see Table 7). Cohen .01 is classified as small effect, while .06 is classified as moderate effect and .14 is classified as large effect (Pallant, 2017). This result explains that the materials applied in virtual reality supported experimental group increases academic achievement more when compared with the animation supported experimental group and the control group. Virtual reality supported applications increase students' academic achievement. There are similar studies in literature (Arıcı, 2013; Chen et al., 2007; Coruh, 2011; Kayabaşı, 2005; Topuz, 2018). Topuz (2018) examined the effect of virtual reality and three-dimensional desktop software in anatomy education on academic achievement. As a result of the study, virtual reality method was found to increase academic achievement. Arıcı (2013) examined the effect of virtual reality software on academic achievement of students in astronomy and concluded that virtual reality software increased students' academic achievement. It is seen that the structures and organs that make up the circulatory system benefits students in the formation of students' minds. In this way, it is seen that there is an increase in the academic success of the students.

It was tested in the study whether there were significant differences between cognitive load scale scores of control and experimental groups. Significant difference was found between the cognitive load scale scores of the groups (p<.05: see Table 12). Students' cognitive load increases as their scores from cognitive load scale increase. Cognitive load theory advocates the use of suitable materials to decrease the cognitive load that will occur in the limited memory of students (Cierniak, Scheiter, & Gerjets, 2009). Materials prepared according to cognitive load theory decrease students' cognitive load. This way, academic achievement, and efficiency of students with low cognitive load increase (Kaya, 2015). The increase in students' cognitive load shows that they show more cognitive effort. Cognitive load scores of virtual reality supported experimental group were found to be lower when compared with the other groups (see Table 11). Virtual reality materials developed in accordance with cognitive load theory have prevented students from having excessive cognitive load. While the instructional designer organizes the content or material, it can positively or negatively affect the amount of cognitive load that may occur on the cognitive system of the student. Although the nature of the content is not complex, the way of presenting the information prepared by the instructional designer can lead to excessive cognitive activities (Paas & Van Merrienboer, 1993). The developed material has been remained loyal to this principle. Although similar studies are not common in literature, studies can be found on the effects of technology supported materials on cognitive load. In their study, Kablan and Erden (2008) reported that technology supported materials affected students' cognitive load levels and enabled them to show less effort. Kılıç and Yıldırım (2010) examined the effects of three-dimensional virtual environment on students' cognitive load levels. As a result of the study, significant difference was found between students' cognitive load levels in favour of the experimental group. Since cognitive level of the Virtual Reality Supported Experit Group group was lower, it can be said that they showed less effort. Kaya (2015) reported that technolmenogy supported material affected students' cognitive load. Aytekin (2019) concluded that technology supported activities affected students' cognitive levels. There are studies with contradicting results in literature. Cansız (2012), concluded that technology supported material did not have any effect on students' cognitive load levels. Özer (2017) examined the effects of technology supported material on students' cognitive load levels. As a result of the study, it was concluded that technology supported material did not have any effect on students' cognitive load levels.

The data obtained from students' cognitive level scale were interpreted. When pretest cognitive levels of control group students were examined, the highest percentage was found in application (47.917%) step (see Table 6). According to Üner (2010), cognitive levels of control group students were in application step. When pre-test cognitive levels of animation supported experimental group students were examined, the highest percentage was found in application (49.265%) step (see. Table 4). According to Üner (2010), cognitive levels of animation supported experimental group students were in application step. When pre-test cognitive levels of virtual reality supported experimental group students were examined, the highest percentage was found in application (46.527%) step (see Table 6). According to Üner (2010), cognitive levels of virtual reality supported experimental group students were in application step. Post-test data of students from cognitive level scale were interpreted. When post-test cognitive levels of control group students were examined, the highest percentage was found in application (61.72%) and analysis (61.72%) steps (see Table 7). According to Üner (2010), control group post-test cognitive levels were in application and analysis step. When post-test cognitive levels of animation supported experimental group students were examined, the highest percentage was found in information (67.50%) step, followed with analysis (66.427%), comprehension (57.412%) and application (55.00%) steps (see Table 7). According to Üner (2010), animation supported group post-test cognitive levels were in information step. However, analysis step was very close to information step as percentage. When post-test cognitive levels of virtual reality supported experimental group students were examined, the highest percentage was found in information (68.125%) step, followed with comprehension (65.714%), application (65.00%), evaluation (64.57%), analysis (60.00%) and synthesis (57.145%) steps (see. Table 7). According to Üner (2010), cognitive levels of virtual reality supported experimental group students were in information step.

The highest difference between the pre-test and post-test cognitive level percentages of control group students were in information (22%) and analysis (22%) steps. The highest difference between the pre-test and post-test cognitive level percentages of animation supported experimental group students was in information (29%) step. The highest difference between the pre-test and post-test cognitive level percentages of virtual reality supported experimental group students was in evaluation (48%) step, followed with synthesis (42%) and information (40%) steps.

Pre-test and post-test CLES analyses of groups were made. Cognitive level ranking of control group students was found to be similar in terms of their scores from CLES. Only information step was found to be in an upper level. The reason for this was the fact that information step requires the identification and memorization of basic information and concepts. At the same time, the highest difference in pre-test and post-test correct answer percentage of control group was in information step. This result shows that control group students mostly had information, comprehension, and application steps, which are lower cognitive levels. Cognitive level ranking of experimental group students was found to be similar in terms of their scores from CLES. Application and information steps were found to replace each other in ranking between pre-test and post-test. Information step was also found to have the highest difference in correct answer percentages in terms of pre-test and post-test scores. Animation supported experimental group students were found to be in information, analysis, and comprehension steps mostly. Students were found to have moderate cognitive level in terms of skills of recognizing and solving information and making associations between parts. Differences were found in cognitive level rankings of virtual reality supported experimental group students in terms of their pre-test and post-test CLES scores. Information and comprehension levels were found to have the highest correct answer rates in terms of post-test scores. The main reason of this situation is the fact that these steps, which are higher cognitive levels, test skills such as recognizing and internalizing Information. The highest difference in pre-test and post-test correct answer percentages of virtual reality supported experimental group students was in evaluation and synthesis steps. According to Üner (2010), these higher cognitive levels steps are steps in which information is uniquely turned into different forms and inferences and interpretations are made. Üner (2010) and Wilen (1991) accept the step with the highest percentage as cognitive level. However, this result contradicts with the results of the present study. In addition to the step with high correct answer percentage, it can also show the situation in step or steps with the highest change.

Virtual reality materials were found to increase students' cognitive levels. Schools are expected to educate students to have high cognitive levels. For this reason, various software and hardware are developed. However, the two or three-dimensional materials developed cannot help students to reach these goals. Materials which serve lower cognitive level such as recognizing and internalizing information are developed. Although animations are widely used today, they appeal to a limited cognitive area. They do not allow original transformation of information to different forms by students. For this reason, animation use appeals to lower and moderate cognitive level. The results of the present study support this finding. When the results obtained were examined, it was found that animation supported experimental group had moderate cognitive level. On the contrary, virtual reality materials provide improvement in all cognitive levels of students. When the results of the study were examined, higher cognitive levels of virtual reality supported experimental group were found to be higher when compared with the control group and animation supported experimental group. Virtual reality provides students a chance to interact and contributes to creative and unique learning of information. This way, students have high cognitive levels. This situation is supported by the study findings. Virtual reality supported experimental group students have high post-test cognitive levels.

Circulatory system has attainments that appeal to high cognitive levels. For this reason, students are asked to schema and associate many concepts while they are learning the subject. At this point, virtual reality software helps students to realize this aim. Rather than education through direct presentation of information, practices in which information is structured and permanent learning takes place are preferred. For this reason, the interaction provided by virtual reality software causes positive changes in students' cognitive levels, academic achievement, and cognitive load.

## Suggestions

Some suggestions were made for future studies in relation to the present study.

- Studies conducted in virtual reality can be performed with larger scale measurement tools.
- Data collection instruments which measure different learning products can be used, which is one of the limitations of the present study.
- Sample group of the study can be extended to include larger groups.
- This way, the effects of virtual reality materials can be evaluated in a more different and effective way. For example, studies can be conducted for the improvement of different skill sets, apart from science and biology subjects. In particular, studies that support the development of creative thinking skills can be carried out. Different physical places can also be used to develop different perspectives, for example in out-of-school learning environments. It is recommended to use VR at different grade levels, for instance, in the preschool period. VR can be used to develop students' imaginations and understand science.
- Circulatory system unit can be extended, which is one of the limitations of the study. Studies can be conducted on different units and subjects and the efficacy of virtual reality materials can be researched.
- Studies on 6th-graders can be conducted on students receiving different levels of science education, for example preschool.
- Studies can be conducted in areas with different physical environments.
- Virtual reality materials can be developed for larger populations in schools by experts.
- The materials developed can be adapted suitably to course books and the curriculum.

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