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The Effect of Teaching Science with Digital Games on Students' Cognitive Structures and Conceptual Changes

Dijital Oyunlarla Fen Öğretiminin Öğrencilerin Bilişsel Yapılarına ve Kavramsal Değişimlere Etkisi

Kevser Arslan[1*]
Aslı Görgülü Arı[2]

***Sorumlu yazar**
Corresponding author

[1]Doktora Öğrencisi, Yıldız Teknik Üniversitesi, Türkiye
PhD Student, Yıldız Technical University, Turkey
arslankevser96@gmail.com
ORCID ID https://orcid.org/0000-0003-0658-7175

[2]Prof. Dr.,Yıldız Teknik Üniversitesi, Türkiye
Prof. Dr., Yıldız Technical University, Turkey
agorgulu@yildiz.edu.tr
ORCID ID https://orcid.org/0000-0002-6034-3684

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ÖZ

Bu çalışma, dijital oyun ile gerçekleştirilen fen bilimleri öğretiminin öğrencilerin mayoz bölünme konusundaki bilişsel yapılarına ve kavramsal değişimlerine olan etkilerinin incelenmesini amaçlamaktadır. Çalışmanın odak noktası öğrencilerde var olan kavram yanılgılarının giderilmesi olup, belirlenen amaç doğrultusunda, çalışma grubunu devlet okullarında yedinci sınıf düzeyinde öğrenim görmekte olan 50 öğrenci oluşturmaktadır. Çalışma grubunun belirlenmesinde, amaçlı örnekleme yöntemlerinden kolay ulaşılabilir örneklemeden yararlanılmıştır. Araştırma, ön test-son test tek denekli yarı deneysel desenle yürütülmüştür. Hazırlanan dijital oyun kullanarak belirlenen çalışma grubuna fen öğretimi gerçekleştirilmiştir. Uzman görüşleri doğrultusunda araştırmacılar tarafından hazırlanan mayoz bölünme konusuna yönelik kelime ilişkilendirme testi, veri toplama aracı olarak kullanılmış ve ön test-son test olarak uygulanmıştır. Öğrencilerden elde edilen veriler analiz edilirken, frekans tabloları oluşturulmuş ve öğrencilerin bilişsel yapılarını ortaya koyan kavram ağları çizilmiştir. Öğrencilerin kavramsal değişimleri ortaya çıkarılmıştır. Araştırma sonucunda öğrencilerin mayoz bölünme konusunda yüzeysel kavramlarının derinleştirildiği, var olan kavramsal eksiklerinin giderildiği ortaya koyulmuştur. Çalışma sonuçları dikkate alınarak teknoloji destekli oyunların kavram öğretiminde eğitimciler tarafından faydalanılabilecek araçlar olduğu önerilmektedir.

Anahtar kelimeler
Teknoloji, Fen Öğretimi, Dijital Oyun, Kavram, Bilişsel Yapı, Kelime İlişkilendirme Testi.

ABSTRACT

This study aims to examine the effects of science teaching with digital games on students' cognitive structures and conceptual changes about meiosis. The focus of the study is to eliminate the misconceptions of the students, and in line with the determined purpose, the study group consists of 50 students studying at the seventh grade level in public schools. In the determination of the study group, easily accessible sampling, one of the purposeful sampling methods, was used. The research was conducted with a pretest-posttest single-subject quasi-experimental design. Science was taught to the determined study group using the prepared digital game. The word association test on the subject of meiosis, prepared by the researchers in line with expert opinions, was used as a data collection tool and applied as a pretest-posttest. While analyzing the data obtained from the students, frequency tables were created and conceptual networks that revealed the cognitive structures of the students were drawn. Students' conceptual changes were revealed. As a result of the research, it was revealed that students' superficial concepts about meiosis were deepened and their existing conceptual deficiencies were eliminated. Considering the results of the study, it is suggested that technology supported games are tools that can be used by educators in teaching concepts.

Keywords
Technology, Science Teaching, Digital Game, Concept, Cognitive Structure, Word Association Test.

INTRODUCTION

The rapidly changing technology in all areas of life finds its place in the teaching process and shows its reflections day by day. Technological developments are always creating new and exciting ways to enable learning in the learning process and to meet growing educational needs (Kalogiannakis et al., 2021). It emphasizes focusing on technology and science subjects in a way that reflects the objectives in order to achieve the goals of science education and to reveal the necessary products. Pointing out that technology cannot be separated from science, it is clear that technology should be supported by science teaching (Barak, 2017; Dialoke, 2017; Şahin & Yılmaz, 2020). It is possible to state that technology, which deeply affects the teaching process, is promising in completing the deficiencies in teaching and making the process more qualified. The transformation of the education and training process into the technology dimension leads to changes that may occur in the role of students and teachers. Sırakaya (2019), with the developments in technology in the 21st century; states that it is aimed to raise individuals who can access information, use information in the context of their needs, and produce new information. In addition, it emphasizes the up-to-dateness of the learning process, which includes many factors such as teaching materials, methods used, classroom environment and the roles of individuals. It may be extremely important to move technology elements to the focus of science learning in the context of providing students with the desired skills, facilitating learning environments and achieving the targeted success.

Enabling teachers to use technological tools effectively and creating a blended learning environment integrating technology into science teaching will increase efficiency in learning (Kırındı & Durmuş, 2019). In a content analysis study conducted by Irmak and Demirci Güler (2018), it is recommended that technological course materials be used correctly and appropriately in the learning environment in order to increase the academic success, and attitudes of students towards science. Similarly, Namdar and Küçük's (2018) research on the use of technology in science teaching revealed that students' success, attitude and permanence had a positive effect on. When the literature is examined, there are studies that use technology in science teaching and reveal that technology has positive effects on the science teaching process in many ways (Bano et al., 2018; Barak & Hussein-Farraj, 2013; Başaran & Kılınçarslan, 2021; Bilir &Uyanık, 2019; Ceylan & Seçken, 2019; Chiang et al.,2014; Cho et al., 2018; İzgi Onbaşılı, 2018; Karacı & Güleç, 2019; Kırıkkaya & Şentürk, 2018; Koç Ünal & Şeker, 2020; Lin & Chen, 2017; Mor & Akbaba, 2018; Parong & Mayer, 2018; Sung et al., 2017; Wang & Tahir, 2020; Yılmaz & Yaşar, 2019). On the other hand, it is seen that there are studies that reveal positive teacher and student views on the use of technology in science teaching (Babacan & Şaşmaz-Ören, 2018; Kan & Özmen, 2021; Omurtak, 2019; Sarıoğlu, 2021; Timur et al.,2020).

With the technology gaining value in science teaching environments, digital games are beginning to replace the digital game physically carried out in classroom environments. Riopel et al. (2020) state that digital games can be one of the most popular and effective media used in science teaching. Digital games are in an important position for new generation students with their many innovative structures and qualities (Anastasiadis et al., 2018). Digital games used for educational purposes can place students at the center of the learning process with their interactive and decision-making mechanisms, as well as contributing to visual and auditory learning, thanks to the elements such as graphics, sound, animation, etc. (Savaş et al., 2021). On the other hand, digital games, which gain value by appealing to all age groups, can have a

positive effect on the development of children (Talan & Kalınkara, 2020). Digital games, which can be used as educational tools, come to the fore with their qualities of increasing student motivation, facilitating the learning process and encouraging participation in the lesson, strengthening cooperation and communication, and at the same time making the students active (Anastasiadis et al.,2018). There are also studies showing that the use of digital games in the teaching process increases student achievement (Arslan & Yıldırım, 2021; Chang et al.,2018; Kabak & Korucu, 2020; Li et al., 2021; Saprudin et al., 2019; Schrader & Bastiaens, 2012). It is important in terms of education as it facilitates learning and makes it more enjoyable (Proulx et al., 2017; Zou et al., 2021). It has been determined that digital games increase students' attitudes and motivation towards lessons, as they enable learning by having fun (Sabırlı, 2018). Yang (2012), similarly explains the contribution of digital games to the learning process as applications that enable students to retain information more easily, help active learning and give the opportunity to evaluate themselves. In a synthesis study, it is revealed that digital games can be used in science education to combat negative thoughts in students, to increase learning outcomes and especially to teach difficult concepts in their content (Kalogiannakis et al., 2021). In addition, it is pointed out that games show that they develop problem solving, creative thinking and programming skills (Hava & Çakır, 2017). There are many studies that benefit from digital games in science learning (Dinçer, 2019; Karayılan et al.,2019; Khan et al., 2017; Martin et al., 2019; Dönmez Usta & Turan Güntepe, 2019; Yapıcı & Karakoyun, 2017). In the meta-analysis study conducted by Tsai & Tsai (2020), it was revealed that digital games have a serious positive effect on science learning and facilitate science learning. Similarly, in another analysis study, it is stated that digital games are at a key point in improving the learning process beyond the design environment (Clark et al.,2016).

Within the framework of the study, it is aimed to benefit from the kahoot application of web 2.0 technology. Kahoot has managed to become one of the most popular games among the various educational games that exist recently (Zhang & Yu, 2021). Kahoot can be defined as learning and entertaining web-based software that allows designers to integrate training or exam content into the game structure. It is played depending on the speed of the players giving the correct answer to the questions on a shared screen from their own devices (Bawa, 2019). It is flexible in creating a variety of content that supports different educational domains and tends to be suitable for users of different age groups (Wang & Tahir, 2020; Zhang & Yu, 2021). On the other hand, although it is easy to implement in the classroom environment, it does not require a high-level education. In addition, educator speed and scoring can be shaped by considering student conditions (Plump & LaRosa, 2017). Kahoot is a game-based learning environment that plays an important role in ensuring active participation in learning activities, facilitating teacher evaluation, creating a fun classroom environment, increasing learning, ensuring success, increasing motivation, and encouraging the achievement of learning goals (Alonso-Fernández et al., 2020; Biçen & Kocakoyun, 2018; Warsihna & Ramdani, 2020; Wu et al., 2011). It has been determined that Kahoot application enriches the learning environment, increases student quality, keeps classroom dynamics alive and has the highest impact on learning experience (Licorish et al., 2018). It is emphasized that the Kahoot application can facilitate the teaching of even the most difficult biology subjects by benefiting student motivation and active participation in the classroom (Jones et al., 2019). In this direction, it was decided to test the Kahoot program in the current study and to examine its effect on conceptual learning about meiosis.

Concepts can be explained as images formed in the human mind by grouping them according to their common characteristics based on the similarities and differences of entities, events, objects and ideas (Bahçeçi et al., 2011). Although concepts are seen as mental tools that allow the individual to think, they are seen as an aid in making sense of nature and establishing meaningful communication (Kurt, 2020). As a result of their interaction with the environment, individuals develop experiences to learn new scientific concepts and can create their understanding of science by including them in their learning processes (Soeharto & Csapó, 2022). In this process, in the development of science-related concepts, students may become confused, misinterpret the information, and accordingly misconceptions may arise (Morais, 2013). These misconceptions can occur in formal and informal environments independent of knowledge (Allen, 2014). Before coming to the learning environment, students interpret the events around them based on their own prior knowledge. Concepts that students make sense of with their daily life experiences and learning environments can conflict with scientific information by ascribing false information. It is stated that students have some misconceptions about the concepts related to the subject before or after they come to the classroom (Coştu et al., 2007). It would not be wrong to state that misconceptions can often be encountered in students, on the grounds that science includes many abstract and concrete concepts. Students' life experiences, false generalizations, misinformation by teachers, and conceptual errors in textbooks can be cited as the source of existing misconceptions (Chazbeck & Ayoubi, 2018). Yıldızay (2020) points out that especially students come with many wrong predictions and inconsistencies while attending science classes and states that these wrong concepts create problems in the teaching process. At this point, it can be deduced that the fact that it is highly related to daily life and the existing intersection of many fields and science will highlight the value that should be given to science concepts. Therefore, the need to eliminate the misconceptions in the minds of students in the field of science can be revealed. One of the propositions accepted in the learning process is that learning is a process of conceptual change. Learning can be defined as the process of students' gaining new ideas as well as developing the concepts they have and replacing them with old concepts (Yağbasan & Gülçiçek, 2003). It is among the goals of science education to provide students with the necessary understanding to form solid concepts of science phenomena and to make their reasoning (Hardy et al.,2006). Appropriate scaffolds should be created for structuring students' cognitive participation within the content area (Trundle & Saçkes, 2012). It will be important to eliminate conceptual deficiencies and eliminate misconceptions by revealing existing misconceptions that have taken place in students in the process of learning science. By adopting an understanding that students are responsible for their own learning, providing teaching environments and materials that offer the opportunity to test students' experience of creating their own knowledge will contribute to the concept learning process (Coştu et al.,2003).

Word association test can be used as one of the tools used in the concept learning process. The word association test, as a measurement tool, can play an active role in questioning whether there is a meaningful connection between the concept that takes place in the mind of the student and other concepts. Tests can take an important place in the context of understanding the concepts correctly in the mind and preventing possible misconceptions. The word association test can be defined as the answer word writing process technique by connecting the key concept given to students in any subject with the concepts in their minds within the specified period (Bahar & Özatlı, 2003; Kayhan, 2019). It is used to reveal the adequacy of the

relationship and information network between concepts in long term memory (Bahar & Özatlı, 2003). It helps to determine the cognitive structure of students, which can be used for assessment-evaluation or diagnostic purposes, and the relationships between concepts in this structure or the significance of relationships between concepts (Bahar et al., 2006). It can be explained as the old and common method that answers the question of how students' cognitive structure and connections between concepts can be revealed or by what method (Bahar & Özatlı, 2003). It is clear that the word association test can be used in the concept learning of students in science teaching. The fact that there are many studies indicating that the word association test is used within the framework of science teaching can provide evidence for the necessity of using the word association test in the learning of science concepts (Arslan, Boz & Coştu, 2020; Avcı, 2021; Balbağ, 2018; Kaplan, 2019; Özyurt & Yalman- Efe, 2020; Sarıoğlan & Çelik, 2021; Türksever, 2021).

It can be aimed to increase the concretization and learning products through the use of technology, since the field of biology, which is included in the content of science, gives more space to abstract subjects in terms of content (Namdar & Küçük, 2018). In this respect, it may be important to conduct a technology based education oriented to the subject area of biology. It is thought that the games will support the positive learning of the students in order to provide the visuality that the science course needs and to enable the concretization of the concepts that take place in the minds of the students. At the point of realizing meaningful learning and achieving success in the field of biology, students' learning concepts is shown as the most fundamental factor (Abubakar & Jimin, 2018). Cell cycles, which is one of the main subjects of biology, becomes one of the most difficult subjects because it has abstract concepts in terms of content, and existing concepts have an important place in biology teaching (Aksakal et al., 2015; Dikmenli, 2010; Karataş, 2021). However, it was revealed by Salleh et al. (2021) that one of the subject areas that are difficult to learn in biology is cellular functions. Students who have knowledge about meiosis will be able to positively shape their decision-making skills on genetics and evolution (Wright et al., 2022). Meiosis is among the examples of subject areas that contain concepts that are difficult to learn and understand by students (Metzger & Yowler, 2019). It was revealed that students made conceptual mistakes in the process of explaining and elaborating the steps of meiosis. On the other hand, it has been stated that the conceptual mistakes made are deeply entrenched and cannot be noticed even by educators (Rodríguez Gil et al.,2019). The fact that meiosis includes many abstract concepts together may make it difficult for students to understand and may lead to the formation of misconceptions (Clark & Mathis, 2000; Elangovan, 2018; Özcan et al., 2012). In particular, it has an equational structure with the successive stages of meiosis, the separation steps of the chromosomes, their diverging aspects from mitosis, and their successive division. Therefore, if students do not go deep in their learning processes, students will not be able to make sense of concepts sufficiently and misconceptions will be inevitable (Murtonen et al., 2020). In this context, it is expected that focusing on meiosis, a subject that comes to mind when misconceptions are mentioned, will make the study valuable. It may be important to test the effect of games in revealing and eliminating the misconceptions that may exist in students about meiosis, which is an important part of the field of biology. It is emphasized that it is necessary to produce effective and efficient solutions for teachers' misconceptions in science classrooms (Potvin et al., 2020). It has been stated by science teachers that digital games will make science teaching effective for students and will make the lesson more fun, permanent and active participation (Dönel Akgül

& Kılıç, 2020). Similarly, in another study, it is emphasized that educational digital games are one of the most ideal ways that teachers can benefit from in embodying abstract concepts, developing positive attitudes towards the lesson, teaching complex subjects and increasing their success (İşçi & Yeşiltaş, 2020). At this point, the reason why the subject of meiosis in the field of biology can have abstract and difficult to understand concepts in the context of content may reveal the need to use digital games in meiosis in the study.

When the literature was examined, no research was found that exactly matched the current study. However, it is understood that there are studies that make use of games for concepts. In one study, it was aimed to test the effect of digital game-based learning on student performance and behavioral patterns by using concept mapping-based two-stage tests (Li et al., 2021). Our study differs from the aforementioned study in terms of using kit testing and focusing only on conceptual changes. In addition, while our study focuses on secondary school students, the other study focuses on secondary school students. In another similar study, it is aimed to reveal and eliminate some deficiencies of concepts by learning electrical circuits in an arcade-type game (Mayer & Johnson, 2010). Graded points were made and the teaching was completed with the feedback given to the students at the same time. Our study differs from the study explained by using the subject of mitosis, benefiting from a different game type and scoring method. In another study, it is aimed to teach basic scientific concepts by using one of the digital games, minecraft (Short, 2012). It is understood that there is no study in the literature that shows one-to-one correspondence with the study we will carry out. Therefore, it is foreseen that a study that can be carried out in the field of biology by making use of digital games in the study can contribute to the literature. From this point of view, in this study, it is aimed to examine the effects of digital games on the cognitive structures and concept changes of meiosis topic at the seventh-grade level. Considering the purpose of the study in this study, "How did science teaching with digital games affect the cognitive structures and concept changes of seventh grade students about meiosis?" an answer to the research question is sought.

METHODS

Research Model

The study was carried out using quantitative research methodology and a single group pre-test-post-test quasi-experimental design was used. In this design, the effect of the experimental procedure is tested by a study on a single group. Measurements related to the dependent variable of the subjects are obtained by using the same subjects and measurement tools as pre-test and post-test before the application (Büyüköztürk et al., 2016). The reason for choosing the study model as a single group is to focus on the determined group and to see clearly the misconceptions and information deficiencies in the group. At this point, the students' knowledge about meiosis was taken into account. The aim is to highlight existing misconceptions in students and to make it clear whether existing misconceptions have been eliminated or not.

Study Group

The study group of the research consists of 50 seventh grade students studying at a public school in the 2020-2021 academic years. In the study, easily accessible case sampling, which is one of the purposeful sampling types, was preferred. The easily accessible case sampling

method adds speed and practice to the research. The goal here is for the researcher to easily access the sample and collect the data (Yıldırım & Şimşek, 2018). There are 27 female students and 23 male students in the study group.

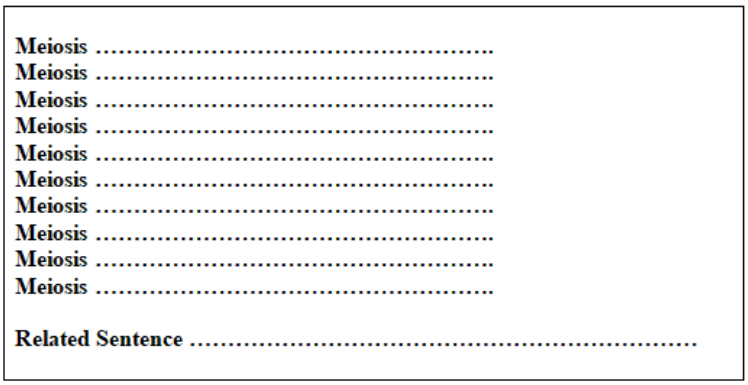
Data Collection Tool

In the study, it was decided that it would be more appropriate to use the word association test to detect students' misconceptions. In the word association test, identifying the misconceptions through the keywords given directly without giving any sentence to guide the students, highlighted the need to benefit from it in the study. For example, the possibility that students can get help from the options in the multiple-choice questions given to the subject in the two-stage tests and write the information in the multiple-choice section in the desired explanation section was considered. On the other hand, the fact that the analysis of staged tests can be long can be annoying for students. When looking at the drawings used in the determination of another concept tool, the idea that it would be suitable for middle school age group students and that the application phase would be easy was evaluated, but it was kept in the background due to the difficulties that may be experienced during the data analysis phase. As Aktaş (2021) states, the message that the student might have given in the drawing may not be clearly expressed and interpreted. In addition, the fact that the study group was a smaller age group at the secondary school level was also taken into account. The fact that the application process of word association tests is not boring and time-consuming (Tokcan & Yiter, 2015) is seen as an important factor in its suitability for the study sample. Therefore, it was concluded that word association is suitable for the nature of the study, considering its suitability for the secondary school group and the positive contributions it can provide to each process of the study.

In the research, the Word Association Test, which was prepared on the basis of the subject of meiosis, was used as a data collection tool. The key word in the prepared kit test was determined by using the subject content in the textbook that students read. Based on student levels, it was decided to include a single keyword, considering that students could establish more relationships in a single word and write the same answer words for other concepts. The key concept of "*Meiosis*" in the word association test was determined in line with the opinions of three field education experts in science education. The word association test about "Meiosis Division" was written 10 times, with each concept one under the other, in order to prevent the risk of chain responses, and students were asked to write the concepts that the keywords brought to their minds. In this case, students will be prevented from returning to the concept they have written, and the situation of writing the word associated with the concept they have written will be eliminated. This will prevent the purpose of the test applied from harming (Bahar & Özatlı, 2003). In addition, students were asked to make a sentence about the keywords and write a single sentence containing the related word.

The word association test prepared by the researcher was carried out as a pre-application with 10 seventh grade students who were selected independently of the determined study group to reflect the target audience. In this context, the problems that may be encountered in the main application have been avoided. In addition, the word association test was completed in approximately one minute during the pre-application. An example of the word association test applied to the students is given in Figure 1.

Figure 1. *Example of Word Association Test*



Implementation Process

The implementation process was completed in 12 lesson hours by including each step in the study. Based on the curriculum, the implementation period and process were created. The subject area studied covers 8 lesson hours (2 weeks) in the current science curriculum. In addition, 4 hours of the elective course given by the researcher at the seventh grade level were included in the application process. Thus, the implementation process was completed in 12 lesson hours in total. In the group determined within the scope of the research, science teaching was carried out with the Kahoot application, which is one of the digital games. For a better understanding of the application process, the application period of the experimental group is given in Table 1 in summary form.

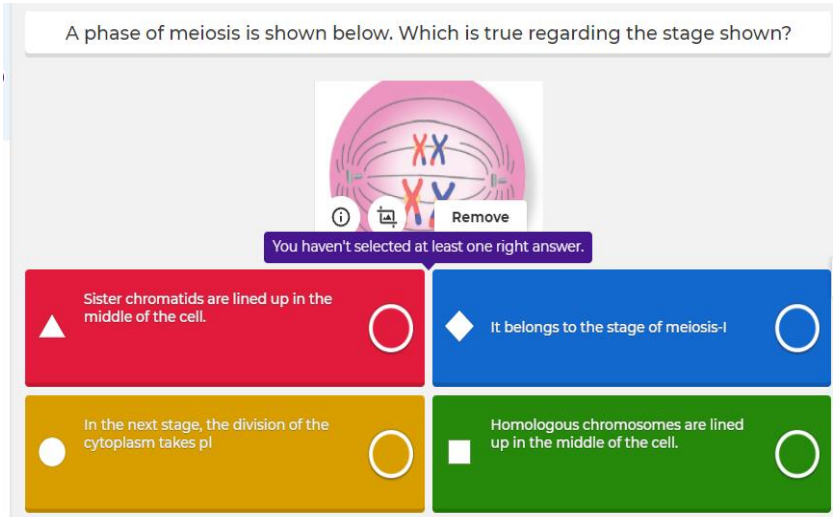
Table 1. *Implementation Process Followed in the Study*

Hour	Implementation Process
1	Introducing the word association test, making the pilot application and applying it as a pre-test
1	Introducing the Kahoot app
3	Explaining the subject of meiosis on Kahoot
4	Application of kahoots created by the teacher for each stage of meiosis to students
2	Students' creation of a mixed kahoot of meiosis
1	Introducing the word association test, making the pilot application and applying it as a post-test
Total	12 Lesson Hour

When Table 1 is examined, the application stages followed in the research and the times given for each stage are seen. The word association test prepared for the subject of meiosis, which was determined as a data collection tool before the application, was applied to the students as a pre-test. Although the students may not have done a word association test before, how to apply the test was introduced and a pilot application was made with a different keyword. The Kahoot application was introduced to the students and shown on the application. Necessary information about Kahoot application and usage is given. Theoretical information about meiosis in the current curriculum was given to the students during 3 course hours. The narration of the subject was completed together with Kahoot. While giving theoretical information about meiosis, only direct expression was used. No technique other than the Kahoot technique was used. Thus, the effect of other variables is limited.

In the next stage, a total of 9 kahoots belonging to each stage of meiosis (including the preparation stage) were prepared by the teacher. There are 10 questions in each prepared kahoot. While preparing the questions, it was especially focused on the misconceptions of the students about meiosis. It is aimed to be noticed by the students and teachers by including the questions in which the misconceptions that can be found in the students are at the forefront. The students were divided into groups so that they could easily experience and follow each other during the application process. The students were formed in 10 different groups of 5 each. The basis of the study was the kahoot application. The kahoot application was used throughout the entire teaching process. After informing the students about the subject, the kahoot application was used in each process of my education. In particular, the students were provided to deepen their knowledge, to teach the basic concepts of the subject, to focus on possible misconceptions and to reveal existing misconceptions through the process. In addition to all these, the students were asked to create their own games by taking into account the important points emphasized. In this way, it is aimed for students to self-assess and control their learning. In this way, 9 different kahoot applications were applied to each group and the kahoot cycle was completed. In the next step, before the groups were distributed, each group was asked to create a mixed 5 question kahoot of meiosis. Thus, students are expected to highlight what they have learned in the process and evaluate themselves. Between the pre-test and post-test period, 12 course hours may be sufficient in terms of validity. At the last stage, the word association test, which was applied as a pre-test, was also applied as a post-test. One of the questions related to the game prepared for the kahoot program used in the teaching process is given in Figure 2 as an example.

Figure 2. *Image of the Kahoot Program Designed in the Study*



Data Analysis

While analyzing the data obtained from the students with the word association test, the intersection point technique was used. Concept networks were created in line with the determined breakpoints. In this technique, the maximum number of answer words given for any keyword in the test is determined as the cut-off point. The answers that are above this response frequency are written in the first part of the concept network, and the determined cut-off point is pulled down at certain intervals. The process continues until all answer words appear in the concept network (Bahar & Özatlı, 2003; Ercan et al., 2010).

From this point of view, for concept networks in the context of the answer word obtained from the students; four intersections were determined: (1) intercept 20 and above, (2) intercept 15-19, (3) intercept 10-14, and (4) intercept 5-9. Each intersection point was determined according to the frequency values of the words written by the students related to the key concepts. In addition, each intersection point given in the concept networks in Figure 1 represents a different colour, and the names of the intersection points and intersection points are written in the same colour. The intersection points in the concept network formed from the data and the colours representing each intersection point range are given below, respectively.

Intersection point 20 and above is indicated with red colour.

Intersection point 15-19 range is indicated by blue colour.

Intersection point 10-14 range is indicated by green colour.

Intersection point 5-9 range is indicated by black colour.

The answer words and written sentences obtained from the word association test, in which the pre-test and post-test were applied to the students, were examined in depth. By calculating the number of answers given to each keyword, a frequency table showing the frequency values of the answer words was created. In addition, each written sentence was grouped into scientific, non-scientific and misconception sentences. In sentence classification, while classifying sentences with misconceptions, the sentences that the students tried to attribute scientific meanings to the key concepts in the sentence but mixed these concepts with expressions and concepts that had wrong and different meanings, were included in this class. A table was created with examples of each grouped sentence.

Reliability and Validity of the Research

Each stage of the study was conducted under the control of experts by interviewing experts in the field of science and with word association study. Research reliability was calculated using the reliability formula of Miles and Huberman (2016). The data obtained were evaluated by two expert educators in the field of science, and it was checked whether there was a consensus among the codes revealed by the experts. The fact that the reliability value was calculated as 0.92 by using the Reliability Formula = Consensus / (Agreement + Disagreement) formula after the coding made can be expressed as an indicator of compliance. The results or inferences obtained in the research should be checked again. The interpretations of the findings should be evaluated by experts (Merriam, 2018). Accordingly, during the data analysis process, the data was analyzed by another expert researcher and a consensus was reached. The logical inferences of the obtained data were checked, and the findings were re-evaluated by science experts. Reductions may occur in the sample group due to various reasons; participants may not continue to work on their own will. It is important for researchers to take necessary precautions against such situations (Fraenkel et al., 2012). During the study, this important situation was taken into account and special attention was paid not to experience a decrease in the number of students. During data collection, different methods that could affect the result were not used, and the effect of the investigated variable in the study was highlighted. The measuring tool used serves the purpose of the study. No intervention was made by the researcher to the process, including the completion process from the beginning of the study.

The researcher should keep his guesses, opinions and theoretical assumptions out of the research (Yıldırım & Şimsek, 2018).

RESULTS

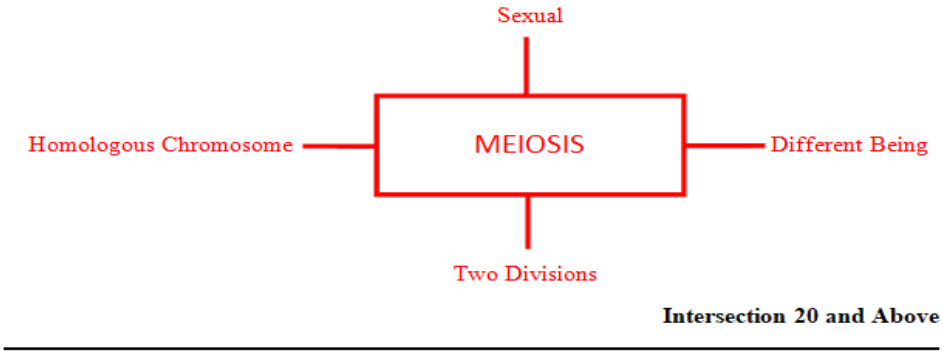
In this part of the study, the analysis findings of the data obtained by the word association test are given.The frequency values of the answer words associated with the key concept in the word association test applied as pre- test and post-test before and after science teaching are given in Table 2.

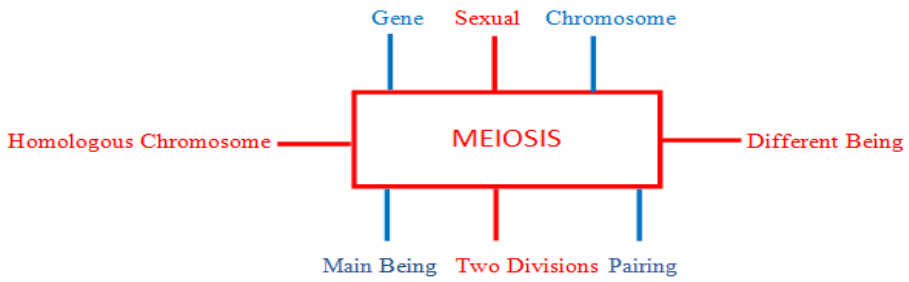
Table 2. *Frequency Values of Answer Words Obtained from the Word Association Test Before and After Science Teaching*

Pre-Test Answer Word Frequency	Post-Test Answer Word Frequency
30	85

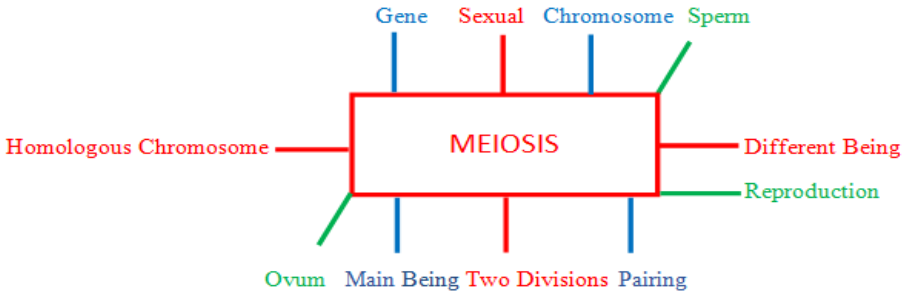
When Table 2 is examined, it is seen that the answers given by the students to the word association test on meiosis before and after the science teaching are seen. The frequency value of the answer words obtained from the students in the pre-test was obtained as 30. In the final test, it is understood that the number of answer words is 85. It is reached that the number of words given by the students has increased approximately twice. The answer words obtained from the students are given in the appendix in detail. The concept networks formed in line with the frequency values of the answer words obtained from the word association test performed as a pre-test before the application are given in Figure 3.

Figure 3. *Concept Network Created from Pre-Test Answers Given to Key Concepts*

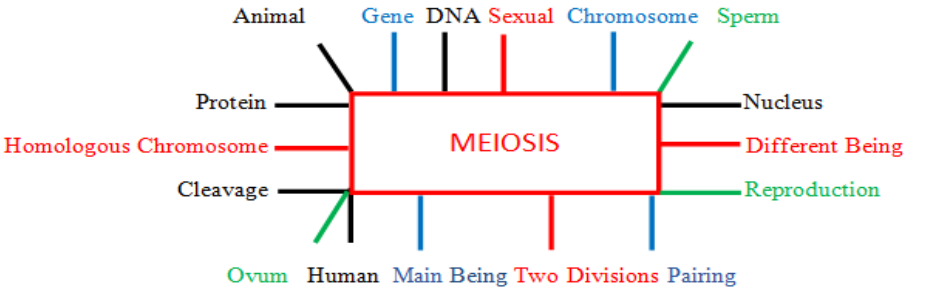




Intersection 15-19 Range



Intersection 10-14 Range



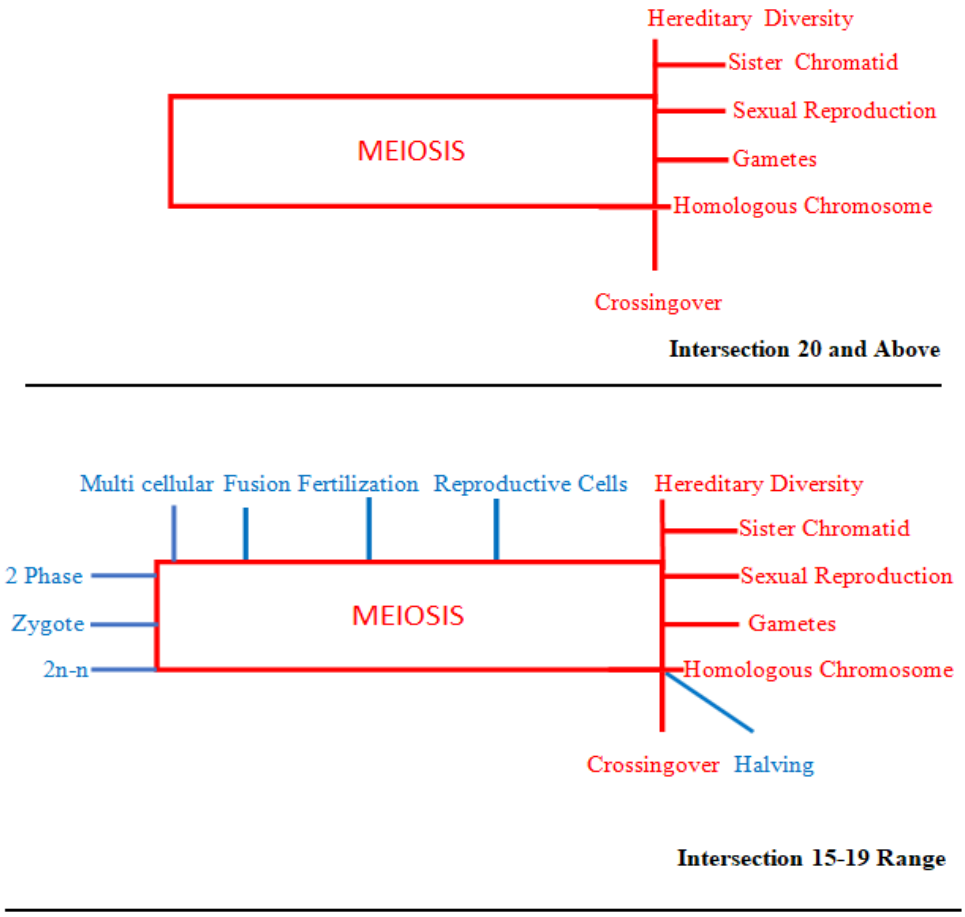
Intersection 5-9 Range

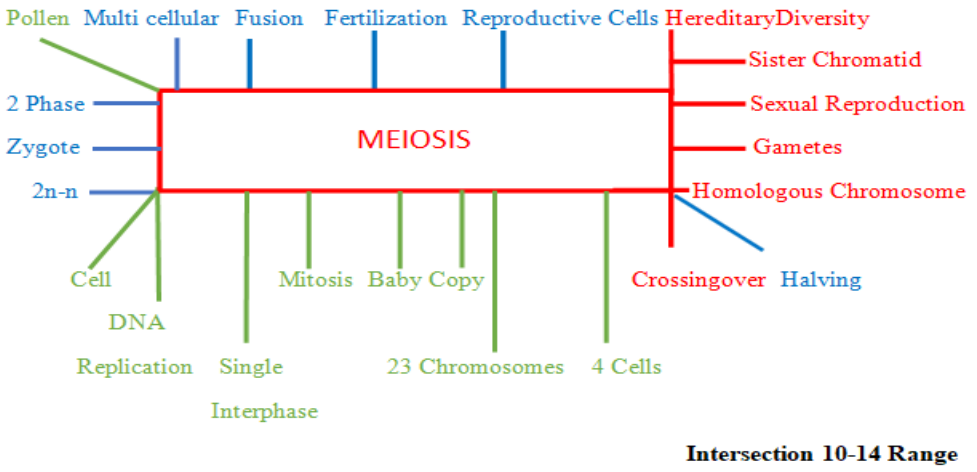
When Figure 3 is examined, the conceptual networks drawn for the determined intersection points of the word association test applied as a pre-test are seen. According to the concept network drawn for the cut-off point 20 intervals (Int 20) and above, it is seen that the number of key concept and answer words is low and the relationship established between key concepts is not sufficient. It is understood that there is a slight increase in the number of key concepts and words associated with this concept to the intersection point of 15-19 (Int 15-19). In this interval, associations were made with the answer words "Chromosome, Gene, Replication and Main Being". It is understood that there is a noticeable increase in the number of answer words related to key concepts in the intersection point range of 10-14 (Int 10-14). It was revealed that in this interval, associations were made with the answer words "Sperm, Ovum and Reproduction". If the intersection point is in the range of 5-9 (Int 5-9), it is seen that the

connections between the answer words increase. It is understood that the association is detailed and the answer words "DNA, Animal, Human, Protein, Cleavage, Nucleus" come to the fore.

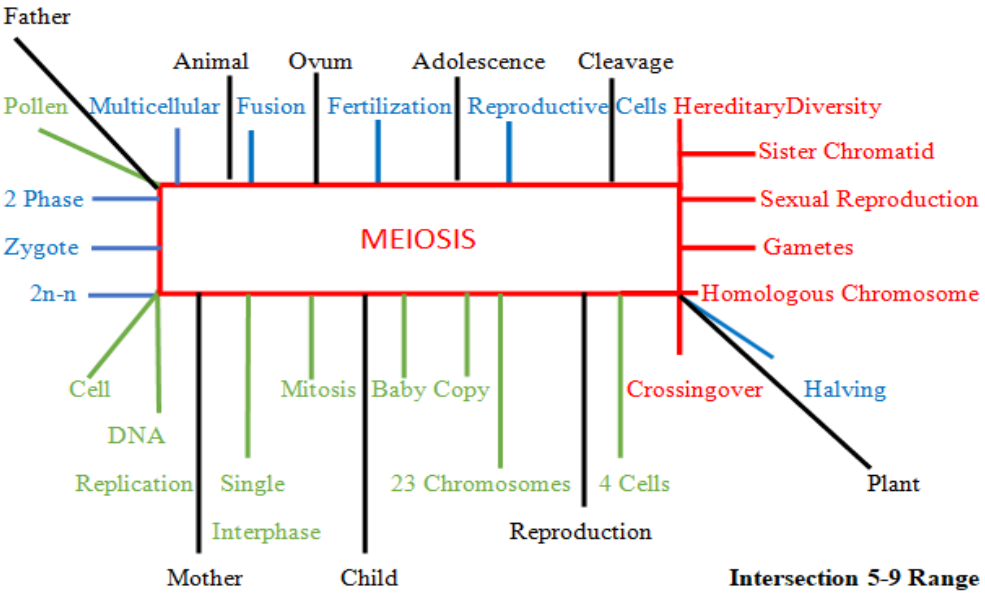
The concept networks formed in line with the frequency values of the answer words obtained from the word association test performed as a post-test before the application are given in Figure 4.

Figure 4. *Concept Network Created from Post-Test Answers to Key Concepts*





Intersection 10-14 Range



Intersection 5-9 Range

When Figure 4 is examined, the conceptual networks drawn for the determined intersection points of the word association test applied as a pre-test are seen. It is understood that a sufficient level of word relation could not be established for the intersection point range of 20 and above and the number of written words was low. It is seen that the answer words of "Hereditary diversity, Crossing over, Homologous Chromosome, Sexual Reproduction, Sister Chromatid, Gametes" are included. It is understood that there is a slight increase in the number of key concepts and words associated with this concept, with the intersection between 15-19 (Int. 15-19). In this range, it is reached that associations are made with the answer words "Multicellular, 2 Phases, Fusion, 2n-n, Fertilization, Zygote, Halving and Reproductive Cells". It is understood that there is a significant increase in the number of answer words related to key concepts with the cut-off point in the range of 10-14 (Int. 10-14). In this interval, it was determined that associations were made with the answer words "Baby, Pollen, Replication, Mitosis, Cell, Single Interphase, 23 Chromosomes and 4 Cells". Finally, if the intersection point is in the range of 5-9 (Int. 5-9), it is seen that the connections between the answer words

increase. It is understood that the association is detailed and the answer words "Sperm, Ovum, Adolescence, Plant, Animal, Mother, Father, Reproduction, Child and Cleavage" stand out.

Before and after the science teaching, the word association test applied as a pre-test and post-test was examined for the classification of the sentences written about the keyword and their frequency values are given in Table 3.

Table 3. *Frequency Values of Sentences Regarding Key Concepts in Word Association Test Before and After Science Teaching*

	Number of Sentences Containing Scientific Information	Number of Sentences Containing Non-Scientific or Superficial Information	Number of Sentences Containing Misconceptions	Empty
Pre-test	10	18	11	11
Post-test	35	9	4	2

When Table 3 is examined, the classifications and frequency values of the sentences written for the words answered by the students to the word association test on meiosis before and after the science teaching are seen. It is understood that 13 of the sentences for the answer words obtained from the students in the pre-test contain scientific information, 18 contain non-scientific information, 11 contain misconceptions, and 8 are left blank. In the post-test, it is seen that 35 sentences contain scientific information, 9 contain non-scientific information, 4 contain misconceptions, and 2 are left blank.

The examples of the classification of the sentences written about the keyword in the word association test applied as pre-test and post-test before and after science teaching are given in Table 4.

Table 4. *Examples of Sentences Regarding Key Concepts in the Word Association Test Before and After Science Teaching*

	Example Sentences Containing Scientific Information	Example Sentences Containing Unscientific or Superficial Information	Example Sentences with Misconceptions
Pre-test Example Sentences	Humans reproduce by meiosis.	We were born by meiosis	Sperm and ovum cells under gomeiosis.
	It occurs in reproductive cells.	Genes come from mom and dad.	During meiosis, there are two preparatory phases, two nuclear divisions and two cytoplasmic divisions.
	The male reproductive cell is the sperm, and the female reproductive cell is the ovum.	It is different from mitosis.	As a result of meiosis, 2 cells are formed.
	As a result of meiosis, 4 cells are formed.	Not always occur	It is also seen in body cells.

	-	-	The number of chromosomes doubles
	Gametes under gomeiosis.	That's why we're different from our mom and dad.	The cell can repeatedly under gomeiosis.
	During meiosis, interphase takes place once.	The two stages of meiosis are different from each other.	Homologous chromosomes move in meiosis.
	Homologous chromosomes move in meiosis-I, and sister chromatids move in meiosis-II.	All three of my brothers are different from eac hother.	Meiosis is a reproductive cell.
Post-Test Example Sentences	In meiosis, the number of chromosomes is halved.	It allows people to be diverse.	Meiosis reproduces asexually.
	The male reproductive cell in the plant is pollen.	Meiosis Allows children to be born.	In the plantcell, the female organ is pollen.
	It provides hereditary diversity by Crossing-over	It is for human reproduction.	It is seen in all living things.
	Meiosis enables reproduction in multicellular organisms.	If a baby doesn't look like its mother, it looks like its father.	-
	Meiosis begins at puberty.	-	-
	A cell that has under gonemeiosis does not under gomeiosis again.	-	-
	The second meiosis is mitosis.	-	-

When Table 4 is examined, it is seen that sample sentences belonging to the classification of the sentences written for the answers given by the students to the word association test on meiosis before and after the science teaching are seen. For example, "Sperm and ovum cells undergo meiosis." When the sentence is examined, the fact that the sperm and ovum cells are formed as a result of meiosis and cannot undergo meiosis again can show that the sentence contains a misconception. On the other hand, "The male reproductive cell is the sperm; the female reproductive cell is the ovum." There is no error in the sentence. Also, "This is why we are different from our mother and father." The sentence emphasized hereditary diversity, but while expressing it, scientific language is avoided.

DISCUSSION, CONCLUSION and RECOMMENDATIONS

Within the framework of the research, it is aimed to examine the effects of science teaching, which is carried out with a digital game, on students' cognitive structures and concept changes about meiosis.

It is noteworthy that there is a difference in the number of answer words that students associate with meiosis concepts before and after science teaching. At this point, it has been seen that technology based science teaching can increase the level of conceptual knowledge. On the one hand, it was determined that there was a decrease in the number of non-scientific knowledge and sentences containing misconceptions in students before the application, together with the science teaching. On the other hand, it was revealed that the sentences containing scientific information increased compared to the pre-test. In this sense, it is possible to state that digital game teaching can have a positive effect on science concepts. In addition, encountering students who did not write any sentences for the key concept may be an indication that the students have a limited amount of knowledge about these concepts. Therefore, similarly it can be deduced that the noticeable decrease in the number of empty sentences in the post-test spreads the knowledge network of the students to a wider range.

When the created concept networks are examined, it is seen that the words obtained in the post-test are more than the words obtained in the pre-test. At this point, it can be said that the concepts related to meiosis, which are associated by students, increase in the posttest (39; 85). This increase can be seen as a sign that students' conceptual knowledge expands after science teaching. In addition, the writing of the answer words associated with the key concepts by the student's shows that the knowledge level of the students was not zero before the instruction and they had some knowledge about the subject. On the other hand, it brings to mind the possibility that students may have made a connection with their past knowledge on mitosis, by reasoning that the students studied the subject of mitosis according to the order in the curriculum before the subject of meiosis.

When the literature is examined, it is pointed out that digital games designed effectively in the science education process are promising in the teaching process and can form a basis for student learning. It has been demonstrated that there is a potential for facilitating learning (Chen et al., 2020; De Gloria et al., 2014; Eftimova et al., 2021; Gros, 2007; Sabırlı & Coklar, 2020; Sung & Hwang, 2018). Therefore, in the context of the study, the benefit of digital games on meiosis can be an indicator of the positive effect it has on science teaching. Through digital games, students tend to apply concrete concepts instead of abstract concepts in the learning process, they understand the subject better and it is easier to learn (Akgül & Kılıç, 2020). Studies show that by using digital games in the teaching process, it can be easier for students to learn scientific concepts (Li & Tsai, 2013; Li et al.,2021; Mayer & Johnson, 2010; Short, 2012; Tsai & Tsai, 2020).

In a study (Jones et al., 2019), which can be valuable in terms of providing a basis for our study, kahoot was used in the field of transcription in the field of biology and it was stated that the application had a positive effect on helping students learn by actively engaging them. In this context, it is possible to say that the findings of our current study overlap with the literature. It is emphasized by Anastasiadis, et al. (2018) that the use of digital games in education creates a student-centered learning environment by providing opportunities for students to gradually

transfer concepts and direct them to the goal. Digital games may be important in terms of teaching scientific concepts and facilitating the retention of the concepts (Hsu et al.,2012; Yang & Chen, 2021). Similarly, in a study conducted by Anderson & Barnett (2013) with digital games, it was revealed that students easily understood the concepts they had difficulty with. In addition, it has been determined that students have gained experience of thinking about scientific concepts by putting their intuitive knowledge, which they have developed with the immersive nature of digital game environments, into practice. It is also stated that it can serve students to learn scientific content that we can describe as complex. The necessity of highlighting the potential of digital games in terms of learning and understanding scientific concepts in science teaching is emphasized here (Hussein et al.,2019). On the other hand, considering that concept teaching may be related to the level of success, it can be stated that digital games can contribute to concept learning as well as improving skills related to academic performance (Best & Miller, 2010; Peng & Kievit, 2020).

With the advantage of providing visuality, digital games can help difficult to learn subjects to be more understandable (Alan, 2017). In this context, the benefit of digital games cannot be ignored when the situation that each stage of meiosis requires visualization. On the other hand, experiencing a conceptual change in the subject may be related to the motivation and desire to learn that they may have at some point. As a matter of fact, digital games can fulfill this task as they increase students' desire to be involved in learning and encourage learning activities (Wati, 2020). In a study that parallels the findings of the study, it is stated that the use of digital games on subjects that are difficult to understand by students can play an important role in gaining the necessary knowledge infrastructure (Turan Güntepe & Dönmez Usta, 2017). Considering all these results in the literature, it can be easily deduced that the benefit of our study on concept teaching of digital games is supported.

The fact that there are studies in which digital games are used for the field of biology in science and its positive effects on learning have been found, forms the basis of our current research (Alp, 2019; Barak & Hussein-Farraj, 2013; Jones et al., 2019; Mutch-Jones et al., 2021; Tunç et al.,2018; Wilson vd., 2018; Yapıcı & Karakoyun, 2017). On the other hand, studies highlighting the contributions of the Kahoot application, which was designed as a game within the scope of the study, to the learning process are also compatible with the results obtained in the study (Ares et al., 2018; Biçen & Kocakoyun, 2018; Curto Prieto et al., 2019; Çetin, 2018; Göksün & Gürsoy, 2019; Guardia et al., 2019; Licorish et al., 2018; Murciano-Calles, 2020; Purba et al., 2019; Tóth et al.,2019; Wang & Tahir, 2020).

It was found that the students had misconceptions that the number of cells formed in meiosis is two. The fact that meiosis occurs in two stages and that they have seen that two cells are formed after the first stage may reveal a situation of misperception in their minds. It has been determined that the students confuse the realization stages of meiosis and mitosis with each other. The fact that meiosis and mitosis have adopted that similar events occur in the division of the nucleus and cytoplasm can make it difficult to distinguish the two division types. Similarly, in the study carried out by Bozdağ and Gökçe (2018), the students' finding that they have difficulties in distinguishing between mitosis and meiosis by experiencing confusion at some points is in line with our study results. Although they have gained awareness that the number of chromosomes is halved as a result of meiosis, it is clear that they have deficiencies in terms of why the chromosome number is halved. In addition, during meiosis-I of

homologous chromosomes; during meiosis-II, it was determined that there were conceptual misconceptions in the knowledge of the existence of sister chromatids, but they were eliminated by the science teaching. It has been understood that they have the knowledge that the change of parts in homologous chromosomes during meiosis provides hereditary diversity, and they express it with both scientific and non-scientific information sentences. It was determined that the students had the misconception that there could be two preparatory phases during meiosis. The reason for this misconception may be the thought that DNA replication may be needed twice, on the grounds that two nuclear divisions and two cytoplasm divisions occur during meiosis. In the study carried out by Koç & Turan (2018), it was determined that secondary school students have difficulties in understanding meiosis, which is the basis of genetics, and they have misconceptions. In this context, it is clear that there are misconceptions of secondary school students, as with our research. The conceptual deficiencies of science teachers due to their past experiences can be given as reasons for the formation of misconceptions about meiosis in students. There are studies to support this view, revealing that pre-service science teachers have misconceptions about meiosis (Alkan et al.,2016; Emre & Bahşi, 2006; Kurt, 2020).

In the study, it can be said that after the Kahoot application, students experienced conceptual changes in the context of the data obtained from the word association test. Therefore, it is recommended to use digital games in science classes to help students learn concepts. It is suggested that technology-oriented games can be integrated with different methods and techniques that can be used in science. Kahoot application was used in the study, other studies can benefit from different game creation applications. In this study, meiosis was applied at the seventh-grade level. It can also be suggested as a suggestion for educators to benefit from games in teaching science in another subject area and at different grade levels.

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