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Investigating Middle School Students' Conceptions of Technology: The Effects of Gender and Grade Level* **

Ortaokul Öğrencilerinin Teknoloji Anlayışlarının İncelenmesi: Cinsiyet ve Sınıf Düzeyinin Etkileri

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ABSTRACT

This study aims to investigate middle school students' conceptions of technology through mental models. Furthermore, it also seeks to determine whether middle school students' conceptions of technology differ according to gender and grade level. The study sample included 1038 middle school students. The research employed a writing-drawing activity and the What is Technology? scale to gather data. When the results were examined, it was determined that only 15.90% of middle school students had good mental models regarding the concept of technology, while 42.48% had medium and 41.62% had poor mental models. Generally, students view technology as a tool that makes people's lives easier and associate technology mostly with electrical and electronic devices such as computers, digital tablets, mobile phones, and televisions. The research revealed that while middle school students exhibited an average grasp of mechanical technologies, they struggled to conceptualize basic technologies. We found that middle school students' understanding of technology did not vary by gender, but did differ statistically significantly by grade level. The findings also showed that higher grade levels were associated with a more sophisticated understanding of technology among middle school students. In conclusion, we observed that the mental models clearly express the dimensions of technology as an artifact, a human practice, and its current role in society. It seems that middle school students' conceptions of technology are

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limited to these three dimensions, and students have difficulty grasping the nature of technology in all its dimensions.
Keywords: *Conception of technology, Mental models, Middle school, Students*

ÖZ

Bu çalışma, ortaokul öğrencilerinin teknoloji kavramlarını zihinsel modeller aracılığıyla belirlemeyi amaçlamaktadır. Ayrıca, ortaokul öğrencilerinin teknoloji anlayışlarının cinsiyet ve sınıf düzeyine göre farklılık gösterip göstermediği de belirlenmeye çalışılmıştır. Araştırmaya toplam 1038 ortaokul öğrencisi katılmıştır. Araştırmada veri toplama aracı olarak yazma-çizme etkinliği ve Teknoloji Nedir? ölçeği kullanılmıştır. Sonuçlar incelendiğinde ortaokul öğrencilerinin teknoloji kavramına ilişkin geliştirdikleri zihinsel model düzeylerinin yalnızca %15,90'ının iyi, %42,48'inin orta ve %41,62'sinin düşük düzeyde olduğunu belirledik. Öğrenciler teknolojiyi genellikle insanların yaşamını kolaylaştıran araçlar olarak görmekte ve teknolojiyi daha çok elektrik ve elektronik cihazlarla (bilgisayar, dijital tablet, cep telefonu, televizyon vb.) ilişkilendirmektedir. Ayrıca, öğrencilerin basit teknolojileri kavramsallaştırmakta zorlandıkları, ancak mekanik teknolojiler için ortalama düzeyde performans gösterdikleri belirlenmiştir. Ortaokul öğrencilerinin teknoloji anlayışlarının cinsiyete göre değişmediği, ancak sınıf düzeyine göre farklılaştığı tespit edilmiştir. Bulgular ayrıca, yüksek sınıf seviyelerinin ortaokul öğrencileri arasında daha sofistike teknoloji anlayışlarıyla ilişkili olduğunu göstermiştir. Sonuç olarak, teknolojinin bir eser veya ürün; bir insan uygulaması, pratiği ve teknolojinin toplumdaki güncel rolü boyutlarının zihinsel modellerde açıkça ifade edildiğini gözlemledik. Görünen o ki ortaokul öğrencilerinin teknoloji kavramları bu üç boyutla sınırlı kalmaktadır ve öğrenciler teknolojinin doğasını tüm boyutlarıyla kavramakta zorlanmaktadır.
Anahtar Sözcükler: *Teknoloji anlayışı, zihinsel modeller, ortaokul, öğrenciler*

INTRODUCTION

In the 21st century, advancements in science, technology, engineering, and mathematics lead to quick changes in all aspects of life. Several developed countries, including the United States of America, South Korea, and England, are adopting new approaches, strategies, methods, and techniques in education to keep up with these developments (Kuhl et al., 2019). Nevertheless, the rapidly-changing technology influences both individual and social life, and potentially determines current and future needs. In this case, it can be argued that students should obtain adequate knowledge, skills, attitudes, and habits in this field to capitalize on the opportunities and potential benefits brought about by technology and technological advancements and avoid being excluded from technological developments (Dasgupta et al., 2019; NRC, 2011; Oliveira et al., 2020).

Technology, which has become increasingly important in the current era, has been defined differently in different periods of human history (McNeil, 2002). From ancient times to the present, technology refers not only to the production and development of a product, but also to the knowledge and skills required to produce that product. Due to constantly changing and developing nature of technology, there are different definitions of technology in the literature. For example, the Current Turkish Dictionary defines technology as "applied knowledge that includes the construction methods, tools, equipment, and instruments used in an industry and their methods of use" (TDK, 2022). Encyclopaedia Britannica (2022) defines it as "the application of scientific knowledge to the practical purposes of human life or to the modification and manipulation of the human environment". The common view in many countries is that technology encompasses products designed to meet human needs and desires, and the processes people use to design these products (Hughes, 2004; ITEA, 2007; Kabakçı & Odabaşı, 2004; Pearson & Young, 2002). Technology is not just an object or tool that we use, but it refers to a concept that we can make, learn, or embody (de Vries, 2018, McNeil, 2002). The common point of different definitions is that technology provides the interaction between people and their environment, that it is products and systems developed by people to facilitate people's lives and meet their needs, and that it includes the totality of knowledge and skills used in the process of their development.

It can be argued that technology is a powerful tool that shapes and directs our life. Hence technology literacy (ITEA, 2007), defined as individuals’ perception and understanding of the technologies that surround their daily lives, is important in enabling them to establish work skills and healthy social relationships (Bacanak et al., 2003; Moye & Reed, 2020). In this context, it is asserted that students require technological literacy to be aware, responsible, and engaged in their society, to carry these attributes into the future, and to establish healthy connections (Moye & Reed, 2020; Pearson & Young, 2002). International Technology Education Association (ITEA, 2007) underlines technological literacy as the capacity to comprehend, employ, manage, and assess technology. Therefore, the understanding of technology encompasses not only factual comprehension but also the aptitude to combine knowledge with fresh insights.

In the current era of science education, it is essential to possess information about technology, be aware of its capabilities and limitations, and identify potential challenges and drawbacks resulting from its progress. The ability for students to achieve these objectives necessitates technological literacy. One of these methods is the STEM education approach, which has gained prominence recently. STEM education offers vital knowledge to individuals on how to acquire scientific knowledge and how to apply it (Blom & Abrie, 2021; Koul et al., 2018). Conversely, it can be asserted that technology is the most significant force, from an economic standpoint, in today's world. This is because a large number of jobs and transactions in the economic sectors are currently performed using technology. Additionally, communication and relationships are also conducted with the aid of technological tools and equipment. Thus, developing a sound understanding of the concept of technology and recognizing the importance of technology literacy for individuals is a primary objective of STEM education.

On the other hand, how students perceive, visualize, and conceptualize scientific and technical terms has a significant impact on their learning process (Wellington & Osborne, 2001). Many studies in the psychology of learning and science education have shown how concepts are understood and learned, including research by Gagne & Brown (1961), Buss & Buss (1956), Li (1996), and Meltzer (2002). Craik (1943) also introduced the idea of mental models or mental representations. These are simplified models constructed by individuals through their perception, imagination, and understanding of discourse in their mind. They are represented as either visual images or abstract situations that are not easily depicted (Johnson-Laird, 1983). Mental models refer to internal representations or concepts that learners construct while interpreting the natural world and their everyday routines (Johnson-Laird, 1983; Shepardson et al., 2007). The use of mental models helps students in understanding the causes, factors, and consequences of a phenomenon (Driver et al., 1985; Greca & Moreira, 2000). A mental model is developed to enable students in the classroom to predict and infer about phenomena, assisting students in interpreting and explaining them. Mental models provide a broad understanding of students' experiences and also aid in identifying any inherent biases among individuals. Research indicates that students usually have complex but partial understanding of scientific concepts (Driver et al., 1985). Therefore, teachers should be aware of the necessary approach to ensure learning and rectify students' misconceptions. When new ideas absorb students’ existing ideas and mental models, their conceptual understanding becomes more comprehensive and robust (Byrne, 2011; Greca & Moreira, 2000).

Previous research has shown that students’ views and existing concepts of technology can affect their ability to learn new concepts and knowledge related to technology (Capobianco et al., 2011; Lachapelle et al., 2019; Jones, 2009). For instance, a student who views technology solely as high-tech products could suggest including such products in solutions, even if they are not necessary. More comprehensive experiences with technology increase students' potential to learn about science and technology. On the other hand, if students’ experience and knowledge of technology activities are limited, they will not be able to gain a comprehensive perspective. Most students have difficulty connecting technology to various aspects of technological processes and have little understanding of the social dimension of technology, and how it affects society (Blom & Abrie, 2021; Lachapelle et al., 2019). It is evident that students' current technological concepts, practices, and processes impact their future technology learning. However, further research is necessary to investigate students' technological concepts and how they evolve (Blom & Abrie, 2021; Bulut Özek, 2019; İmer Çetin & Timur, 2020; Jones, 2009; Lachapelle et al., 2019). In light of all this information, this research aims to uncover and analyze middle school students' technology concepts and understandings through mental models.

Studies on Students’ Conceptions and Perceptions of Technology

A review of studies in the relevant literature reveals differences in students' perceptions of technology and deficiencies in their understanding of technology. Liou (2015) conducted a study with approximately 900 high school students, and concluded that students generally associate the concept of technology with electrical devices. Liou (2015) first investigated how high school students associate the concept of the nature of technology (n = 455), and also developed an instrument to measure students' conceptions of the nature of technology. The data obtained (n = 530) confirmed that the instrument was valid and reliable. One of the study's recommendations is that students should be involved in seminars in which they discuss issues related to technology, people, and the environment with their peers, which encourages critical thinking. Similarly, Solomonidou and Tassios (2007) observed in their study that 8-12 year old students defined technology only in terms of new and modern devices such as mobile phones and televisions. The researchers observed that topics such as everyday technologies, technological change, and the use of technology in everyday life are the main topics that students have difficulty understanding and associating. DiGironimo (2011) investigated middle school students' perceptions of technology using a questionnaire consisting of open-ended questions. The results of the study showed that students defined technology as the tools and devices they use in their lives. In addition, the results show that middle school students have developed an understanding of the impact of technology on society, albeit at a certain level. DiGironimo (2011) proposed a conceptual model that explains the nature of technology in five dimensions. The first dimension of this model considers technology as artifacts produced as a result of technological innovation products and processes. The second dimension emphasizes cognitive processes and considers technology as a process of physical and mental creation and development. The third dimension considers technology as a practical application specific to human nature, which includes the social, cultural, and ethical aspects of human beings. The fourth dimension focuses on the history and historical development of technology, and the fifth dimension focuses on how technology is interpreted in today's societies, current and changing transforming technological activities. In the study (DiGironimo, 2011), it was found that students gave little importance to the second dimension, which refers to technology as a process in which creativity is used. Lachapelle et al. (2019) developed the "What is Technology? Instrument" and completed the validity and reliability processes. In their study, they concluded that students between the ages of 8 and 11 associated technology with electricity and electric vehicles. On the other hand, the students had difficulty with simple and mechanical technologies. Similarly, Jocz and Lachapelle (2012) concluded in their previous study that students associated technology with complex and electrical tools. Cunningham et al. (2005) reported that students mostly associate technology with power and electricity, and very few students perceive simple man-made technologies as technology. Lottero-Perdue (2009) found that students defined technology as involving electricity, power and cables and that after the training they received, they were able to associate technology with simple tools. The results showed that before the implementation of the Engineering is Elementary (EiE) curriculum, students were able to make useful and harmful judgments about technology; after the implementation, their understanding of technology improved significantly, but they still needed to be supported with concrete examples. Blom and Abrie (2021) investigated students' perceptions of technology and its relationship to science in a study conducted with high school students. The results show that students have a narrow view of technology and perceive technology as new technological devices and the process of designing and using them. Erişti and Kurt (2011), who investigated fifth grade students' perceptions of technology using the drawing technique, found that after analyzing the data of 28 students who participated in the study, the students defined the concept of technology with the devices they use in their daily lives, such as computers and the Internet. In previous studies, Rennie and Jarvis (1995a, 1995b) also used the drawing method to investigate the factors that influence the perceptions of 2nd-6th grade students in England and Australia about the concept of technology. The results showed that students' age, gender, previous experiences, and abilities influenced their perceptions of technology. For example, 5th grade students have more intense perceptions and interest in technology. Girls' and boys' interest in technology differs to some extent. For example, girls in grades 5 and 6 are significantly less interested in technology than boys. However, in the British sample, a slight difference was observed only in grade 6. Davis et al. (2002), on the other hand, examined elementary school children's understanding of technology and how it changed with grade level, drawing attention to the abstract associations in students' expressions. Therefore, teachers of higher grades should pay attention to them and prefer appropriate pedagogical approaches. Moreland (2004) found that students' school experiences with technology have a positive effect on their perceptions of technology. Furthermore, it was concluded that students who were taught by teachers who had a narrow view of technology stated that it was difficult to work in technology-related professions. Bulut Özek (2019) attempted to determine the perceptions of technology of 6th grade students through the pictures they drew, and the results of the study revealed that there was no significant difference between male and female students. Fırat (2017), who investigated the technological products of elementary school students (n = 239) and their reasoning skills about them, found that students generally associated technology with electrical and modern devices and ignored the negative effects of technology. Research findings indicate that students' perceptions of technological products are significantly influenced by factors such as socioeconomic environment and family educational background. Herdem et al. (2014) examined eighth grade students' perceptions of technology through cartoons they drew. The researchers found that students defined technology primarily as electronic devices, and that there were differences between genders. However, another study (Ergün, 2018) examined middle school students' ideas about technology and engineering, and concluded that students' perceptions of technology were inadequate but did not differ in terms of grade level and gender variables. İmer Çetin and Timur (2020) tried to reveal the views of middle school students on technology with a word association test. The results of the study showed that students viewed technology as tools that make life easier. When the drawings of 8th grade students were examined, it was observed that female students drew home appliances and computers, while male students drew computers, cars, and mobile phones more. It was concluded that the students' general perception of technology was low. Moreover, Karaçam and Aydın (2014) attempted to determine students' perception of technology through metaphors. It was found that students' perception of technology was generally positive and there was differentiation at the level of education, but there was no differentiation in the gender variable. As a result, students' knowledge of the concept of technology is generally associated with the electrical devices and tools they use in their daily lives. In addition, the research results contain different findings according to gender and grade level.

The Significance and Purpose of Study

Determining how middle school students define technology, an abstract and complex concept for students, is important to the success of STEM education and the development of students’ technological literacy. It is also important to examine what students understand by the concept of technology and to have more information about how their understanding has developed and to identify misconceptions. Identifying the factors that influence students' understanding of technology concept is expected to be effective in teaching similar scientific concepts. Science teachers should also be aware of the different understandings that students may have and plan their instruction accordingly. The purpose of this study is to determine middle school students' understanding of the concept of technology through mental models. It also aims to determine whether middle school students' conceptions of technology differ by gender and grade level. This study seeks to answer the following research questions:

1. What are the levels of mental models developed by middle school students about the concept of technology?

2. Do the levels of mental models developed by middle school students about the concept of technology differ by gender?

3. Do the levels of mental models developed by middle school students about the concept of technology differ by grade level?

METHOD

Study Design

In this study, which aims to explore middle school students' conceptions of technology in depth and comprehensively, it is important to collect both qualitative and quantitative data in a way that provides data diversity. In this way, the data obtained can provide a more holistic interpretation of the research problem. Therefore, this study was designed using the convergent mixed methods design (Creswell & Clark, 2018; Leech &

Onwuegbuzie, 2009). The mixed methods research model provides a perspective in which the research problem and topic are addressed more holistically, and qualitative and quantitative research data are collected separately and evaluated together. This allows for a more comprehensive interpretation of the research problem and can guide new research (Creswell & Clark, 2018; Johnson & Onwuegbuzie, 2004; Onwuegbuzie & Combs, 2011).

Different designs can be applied in mixed methods studies (Creswell & Clark, 2018). In this study, the convergent mixed methods design, triangulated mixed research, was used in which qualitative and quantitative data sources were diversified and evaluated together, allowing for a more in-depth analysis of the problem. The data were collected using the survey method (Fraenkel et al., 2012), which aims to reveal the characteristic knowledge and understanding of a study group or population about the research topic. As a result of the various data sources and analyses, the research problem can be interpreted in much more detail, leading to more valid research results.

Participants

The study's accessible population consists of middle school students studying in Konya province and its districts in Türkiye. The accessible population is a realistic choice that a researcher can conveniently access and it allows the researcher to collect data and generalize findings (Büyüköztürk et al., 2018; Fraenkel et al., 2012). In this research, convenience sampling was employed for data collection (Fraenkel et al., 2012). The study involved 1038 middle school students who participated voluntarily and were based in the city center. Data were gathered from three public schools serving primarily families from middle socioeconomic backgrounds. Before the study, ethical approval was obtained, and both participants and their families were informed. Among the participants, 506 (48.75%) were female, and 532 (51.25%) were male students. The grade with the highest participation rate was Grade 6 (n = 304, 29.3%), whereas Grade 8 had the lowest (n = 226, 21.8%) participation rate. Table 1 shows the gender and grade level distribution of the study group.

Table 1. Participants' Gender and Grade Level Distribution

Grade Level	Female (n)	Male (n)	Total (n)	%
5	112	143	255	24.5
6	134	170	304	29.3
7	144	109	253	24.4
8	115	111	226	21.8
Total	506	532	1038	100

Data Collection Tools

In this study, the primary data collection tools utilized were the writing-drawing activity and the What is Technology? scale. The writing and drawing activity aimed to reveal students' mental models of the technology concept, wherein they were provided with a blank paper and instructed to draw and explain their ideas on what comes to mind when they hear/read the term "technology." Students were given at least 15 minutes to finish the task. The student's mental model representations and explanations were assessed using a rubric created by the researchers in accordance with a framework developed by Rennie and Jarvis (1995b) and DiGironimo (2011).

'What is Technology?' scale (WT) developed by Lachapelle et al. (2019) aims to reveal elementary school students' conceptions of technology. The scale is divided into four sections exploring different aspects of students' conceptions of technology. The first section requires students to provide a definition of technology. The second section asks students whether lightning is a kind of technology and asks them to explain the reasons for their answers. In the third section, students were tasked with selecting which statements accurately describe technology. Subsequently, in the last section students were presented with twenty distinct images and required to indicate whether each constituted technology. The original scale has a three-factor structure consisting of non-electrical technologies (f1), electrical technologies (f2), and natural items (f3). The overall

Cronbach's alpha value for the scale is 0.733. The internal consistency reliability measurement for each factor of the scale (f1 α = 0.862, f2 α = 0.66, f3 α = 0.724) is acceptable (α > 0.60).

Validity and Reliability

In mixed method research, researchers may have different interpretations of the concepts of validity and reliability (Creswell & Clark, 2018; Johnson & Onwuegbuzie, 2004; Onwuegbuzie & Johnson, 2006). The viewpoints on these issues vary and remain a subject of debate. For instance, Onwuegbuzie and Johnson (2006) argued that the validity is always prone to improvement in mixed method research and proposed the term 'legitimation' to refer to the process of approval and legitimization. There are three main considerations at this point (Onwuegbuzie & Johnson, 2006). The first concerns the capability of the data to accurately reflect experiences and phenomena (e.g., conversion, minimizing weaknesses). The second is legitimation to ensure that the results are both reliable and confirmable (e.g., multiple validities). The third is the integration of qualitative and quantitative methods, each with different validity qualities (e.g., sample integration). Other options exist for the well-established and commonly used term validity, such as construct validity and quality, which have been proposed in mixed research (Creswell & Clark, 2018). According to Creswell and Clark (2018), validity in mixed methods research can be secured by exercising control over both qualitative and quantitative data. Hence, to draw accurate and comprehensive interpretations from the data, potential threats should be evaluated, and validity should be assessed based on the mixed method employed.

Reliability and validity in mixed methods research can be ensured through various means. Ensuring diversity of participants, consistency and reproducibility of practices can improve the reliability of qualitative data. The internal consistency, construct validity, cultural and linguistic compatibility of the measurement tools used in the study are important for the reliability of quantitative data. To increase the validity of the results obtained in this study, we ensured control over the data collection processes and utilized both qualitative and quantitative data integration, alongside verification methods in the analysis processes, to limit potential threats. Additionally, we sought the support of field and language experts to ensure the quantitative reliability of the research data. Creswell and Clark (2018) assert that validity is open to various interpretations across studies, but its fundamental purpose is to guarantee the quality of the data, obtained results, and researchers' interpretations.

Before conducting data analysis, the accuracy of the collected data was verified, the coding accuracy was tested, and the level of agreement among raters was determined. In order to ensure the reliability of the study, the measurement and data collection tools were evaluated and checked by experts. In addition, Cronbach's alpha used as a measure of reliability, specifically for internal consistency reliability of the scale. The responses provided by the students who participated in the writing-drawing activity were independently coded and scored by three field experts. To determine inter-rater reliability, Krippendorff's alpha reliability coefficient was calculated, which showed a high level of agreement among the raters with a value of 0.92. Krippendorff's alpha values below 0.67 indicate low agreement levels among raters, while values above 0.80 indicate high agreement levels (Krippendorff, 2004). The Turkish scale adaptation ($N = 649$; $\chi 2/df = 2.765$, $CFI = 0.987$, $TLI = 0.985$, $RMSEA = 0.052$) was conducted with the researcher (Lachapelle et al., 2019) approval. The Cronbach's alpha coefficient for the 19-item Turkish WT scale was found to be 0.822. In terms of internal reliability, the scale's dimensions yielded acceptable and satisfactory results (f1: 0.914, f2: 0.673, f3: 0.637).

Data Analysis

The mental models and explanations produced by the students during the writing-drawing activity were grouped into three categories: simple, detailed, and unclear/incomprehensible or none. These categories were based on the drawings and explanations provided on paper. Students' mental model drawings were classified as simple if they contained only one object or item related to technology, detailed if they included two or more objects or items related to technology, and unclear/none if the drawings could not be understood, did not relate to technology, or lacked any representations. Similarly, students' explanations of their mental models were classified as simple if they consisted of a few words or a single sentence that related to technology; detailed if they included several sentences and were related to technology; and unclear/none if they were not related to technology, could not be understood due to incomprehensible wording or syntax, or simply were not provided. The mental model drawings and explanations of students were analyzed based on DiGironimo's (2011) five dimensions of technology ("technology as artefacts, a creation process, a human practice, history of technology, and the current role of technology in society", p. 1341). Accordingly, students' mental model drawings and explanations of technology may be linked to a single dimension or multiple dimensions. The evaluations of students' mental models were assigned scores for each dimension with which they were associated, using the following protocol: 0 points (not understood) for each dimension if incorrect, irrelevant to technology, or incomprehensible; 1 point (very limited understanding) for a single idea or association; 2 points for two separate ideas (partial understanding); and 3 points for three or more ideas (good understanding). Additionally, an extra 1 point was added for each dimension mentioned by the student. As a result, the mental models provided by students were assessed using a scoring system of up to 3 points for each dimension, with a total maximum score of 15 points. Furthermore, a maximum of 5 points were allotted to dimensions that the students mentioned, with a total maximum score of 20 points. Based on the students' responses, their levels of mental model comprehension for the concept of technology were categorized as either good, medium or poor. Students who scored 0-5 points on the activity were classified as having poor understanding of technology, while students who scored 6-10 points were categorized as having moderate understanding, and those who scored 11 or more points were classified as having good understanding of technology. It was observed that students could get a maximum of 15 points from the mental model activity. The data obtained from the activity was analyzed using the descriptive analysis method.

Figure 1 displays the mental models of two female 6th grade students' conceptions of technology. Scoring and evaluation examples for the writing-drawing activity are as follows: Upon analyzing the first student's explanations and drawings, it is apparent that she associates the concept of technology with digital, electrical products, and applications powered by electricity. She earned three points in the “technology as artifacts” dimension for citing appliances such as washing machines and dishwashers, as well as electronic devices like computers, phones, and tablets. Additionally, she received two points in the “technology as a human practice” dimension for mentioning Instagram and WhatsApp applications. Finally, she earned three points in the “current role of technology in society” dimension for citing activities such as online shopping, video chatting with loved ones, and homework preparation. Since the student covered three distinct dimensions, she received an additional three points, bringing her total score to 11 points. This student’s level of mental modeling was evaluated as detailed, and shows that the student has a good understanding of technology. The second student, however, made a more limited association, mentally linking novel electrically powered products to the concept of technology. Since the student only provided examples of technological products, she received 3 points from the “technology as artifacts” dimension and 1 point for the dimension, totaling 4 points. This categorizes the student's mental model level as simple, indicating a poor understanding of technology.

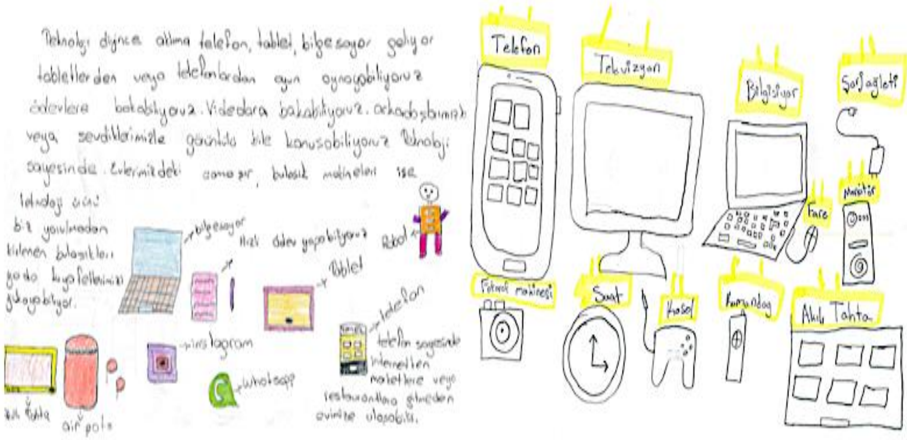

Figure 1. Examples of Students’ Mental Models of the Concept of Technology

While the study's qualitative data were analyzed using descriptive content analysis of codes and themes, the quantitative data were analyzed using descriptive statistics

(Büyüköztürk et al., 2018; Fraenkel et al., 2012; Krippendorff, 2004). The data were evaluated for missing values, normal distribution, and skewness. The kurtosis (0.428) and skewness (0.882) values of the scale vary between -1 and +1, and the histogram and Q-Q plots support normal distribution (Tabachnick & Fidel, 2013). The statistical package program (SPSS ver. 23) was used for analysis of the quantitative data. An independent t-test was conducted to assess potential differences in answers provided by students in the WT scale based on gender. A one-way analysis of variance (ANOVA) was conducted to explore potential differences based on grade level.

Ethical Considerations

This research was approved by both Konya Provincial Directorate of National Education (Date: 21.09.2021, No: E-83688308-605.99-32530062) and Hacettepe University Ethics Committee (Date: 28.07.2021, No: E-35853172-300-00001676756) (Appendix). Prior to participation, students and their families were informed about the study verbally and in writing by using informed consent form, and voluntarily participated in the study.

FINDINGS

Findings Concerning the First Research Question

In order to answer the first research question, the data obtained from the writing-drawing activity was first analyzed. We calculated frequency and percentage values to assess the distribution of technology-related mental models among middle school students. Our analysis reveals that 64.64% (f = 671) of students depicted detailed mental models in their drawings, while 33.04% (f = 343) provided detailed explanations. The results show that 26.20% (f = 272) of students' mental model drawings and 55.49% (f = 576) of their explanations were considered simple. Additionally, 9.15% (n = 95) of the drawings and 11.46% (n = 119) of the explanations were either unclear or absent. Based on this data, it appears that while the majority of middle school students' mental model drawings are detailed, their explanations remain at a basic level. The distribution of technology dimensions mentioned in middle school students' writing-drawing activity indicates that students heavily conceptualize technology as artifacts. In other words, as observed in the data, students' mental models of technology are predominantly represented by products or objects like computers, digital tablets, cell phones, televisions, smart boards, programmed applications, and the Internet. The study revealed that the “technology as artifacts” dimension had the highest attribution (99.23%, f = 1030) among all the mental models. The second most attributed dimension was the “current role of technology in society” (53.28%, f = 553), followed by “technology as a human practice” (43.74%, f = 454). However, the dimensions of the “history of technology” (8.29%, f = 86) and the “technology as a creation process” (8.0%, f = 83) had the lowest attributions among the students' mental models. These findings reveal that middle school students perceive technology solely as artifacts, but they generally lack an understanding of technology as a creation process. In other words, most participants did not conceptualize technology as a process or a system connecting the nature of technology and science (DiGironimo, 2011). Table 2 displays the distribution of the dimensions expressed by middle school students in the writing-drawing activity.

Table 2. Distribution of the Number of Dimensions (N = 1038)

Number of Dimensions Expressed	*f*	%
1	366	35.26
2	282	27.17
3	306	29.48
4	63	6.07
5	21	2.02

Upon analysis of the data, it is evident that 35.26% of middle school students referenced only one dimension in their mental models. 27.17% of students referenced two different dimensions, while 29.48% expressed three dimensions. Merely 6.07% of students expressed four dimensions, and only 2.02% successfully referenced all five dimensions. This finding provides further evidence that only a small number of students can perceive technology in all dimensions, and the majority have limited understanding of the concept. In general, our analysis of middle school students' mental model levels revealed that only

15.90% (f = 165) had a good comprehension for the concept of technology. In contrast, 42.48% (f = 441) had a medium level, and 41.62% (f = 432) had poor mental model levels. It is evident that the mental model levels of middle school students regarding the concept of technology are generally at a medium or poor level.

In the middle school students' mental models, 58 different items were observed. The most commonly associated technological items were cell phones (f = 768), desktop computers (f = 435), laptops (f = 381), tablets (f = 358), phone applications (f = 306), television (f = 279), the Internet (f = 182), robots (f = 104), smart boards (f = 103), and smart watches (f = 73). The majority of middle school students conceptualize technology with electrical objects or products, as evidenced by the distribution of items listed in writing-drawing activity. Of the items mentioned, 92.49% were electrical, 7.16% were non-electrical, and only 0.35% were natural. Further analysis of the research question employed data obtained from the WT instrument. The responses and written explanations of middle school students regarding whether lightning is a kind of technology were examined. Out of all the students, 16.3% believed lightning to be a type of technology, while the remaining 83.7% disagreed. The majority of those who answered 'no' explained that lightning is either a natural phenomenon, not made by humans or a result of non-human activity. Based on the findings, it can be concluded that most middle school students possess a precise understanding that lightning is not a kind of technology. However, students who answered 'yes', indicating that lightning is a kind of technology, held varying notions and understandings about the concept of technology. These students generally associated lightning with technology due to logical reasoning stemming from electricity and light phenomena. Table 3 presents statements from the students who considered lightning as a kind of technology.

Table 3. Sample Statements from the Participants (participant code, gender, and grade level)

Statements (participant code)	Gender	Grade level
"Yes. Because it gives off light." (808EN, F-5)	Female	5
"Yes. Because it is also a power and some people use the power of this lightning (high power)." (733AN, M-5)	Male	5
"Yes. The reason: it is an energy that hits the ground hard due to the effect of icing in weather such as rain and snow." (734TA, M-6)	Male	6
"Yes. Lightning is a combination of clouds and when it hits the ground there are some electrical wires under the ground" (744EU, F-6)	Female	6
"Yes. Because lightning is the electric transmission between the earth and the sky." (342HA, F-7)	Female	7
"Yes. What powers technology is electricity. Electricity is a type of energy. The best example is lightning." (347EF, F-7)	Female	7
"Yes. Yes, lightning is a kind of technology. Because lightning is formed by collecting the electricity in the air." (828AE, F-8)	Female	8
"Yes. In my opinion (my theory) lightning is technological. Actually, lightning is caused by technology. I think that artificial lights, which is wonders of technology, transmit the light they reflect to the sky, and an incredible light appears in the clouds and the sky, and the incoming lights explode to form lightning." (780YZ, M-8)	Male	8

The distribution of the statements selected by the middle school students' in response to the question "Which of these describe technology?" in the WT scale is given in Table 4.

Table 4. The Distribution of the Statements Selected by the Students

Statements (Which of these describe technology?)	Selected		Unselected	
	f	%	*f*	%
Must be a computer	776	74.8	262	25.2
Must solve a problem	713	68.7	325	31.3
Must be new or modern	599	57.7	439	42.3
Must be a kind of power	811	78.1	227	21.9
Must have parts that move	431	41.5	607	58.5
Must be invented by people	809	77.9	228	22.1
Must use electricity or power	811	78.1	228	22.1
Must have a computer inside	499	48.1	539	51.9
Must have a screen to look at	709	68.3	329	31.7
Must be a thing you can touch	715	68.9	323	31.1

When Table 4 is analyzed, it can be seen that middle school students most often describe technology as "must be some kind of power" (f = 811), "must use electricity or power" (f = 811), and "must be invented by people" (f = 809). These findings align with the results derived from the assessment of students' mental models and their responses to the lightning question. The least selected statements that the students associated with technology are "must have parts that move" (f = 431), "must have a computer inside" (f = 499), and "must be new or modern" (f = 599). The research findings indicate that while a majority of students do not associate technology with the presence of movable parts (58.5%) or having a computer inside (51.9%), a significant group of participants do associate these features with the concept of technology. Specifically, 41.5 and 48.1

percent of the students consider the presence of movable parts or having a computer inside as essential for technological objects. Overall, it can be concluded that middle school students generally perceive technology as man-made, power requiring, energy-demanding computerized objects and they can be used to solve problems.

The correct answer rates of middle school students for electrical, non-electrical and natural items in the WT scale are shown in Figure 2.

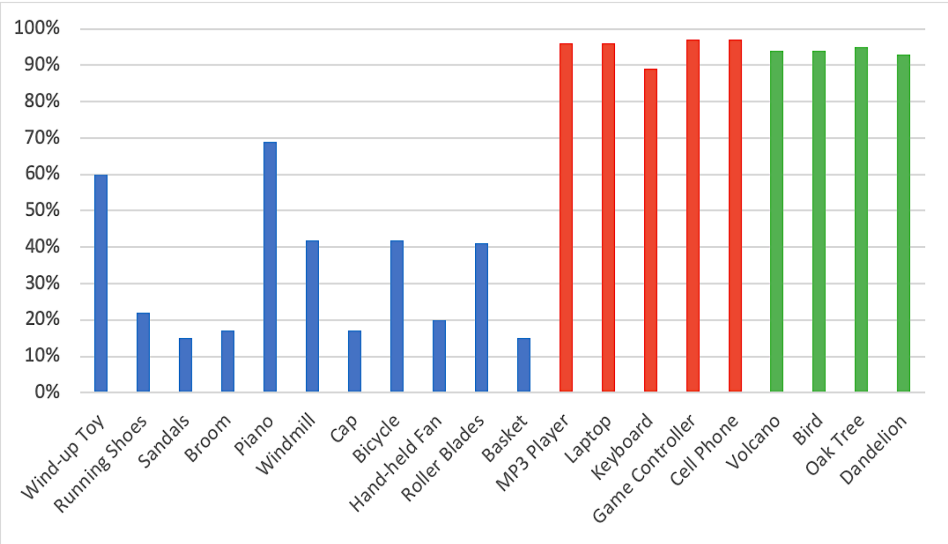

Figure 2. Students' Correct Answer Rates of Electrical, Non-electrical and Natural Items

When examining Figure 2 for non-electrical items, it becomes evident that middle school students correctly answered with high rates for piano (69%), wind-up toy (60%), windmill (42%), bicycle (42%), and roller blades (41%). However, the items with the lowest correct scores observed were sandals (15%), basket (15%), broom (17%), cap (17%), and hand-held fan (20%). These findings provide clear evidence that for non-electronic devices, some middle school students link their understanding of technology to objects with moving parts. As for electronic items, the majority of students answered the question correctly and achieved very high scores on items such as game controller (97%), cell phone (97%), laptop (96%), music (MP3) player (96%), and keyboard (89%). It can be concluded that middle school students possess a high conception of electrical items. They tend to associate the concept of technology with electrical items. As anticipated, most middle school students attained also high scores for natural items. Specifically, oak tree (95%), volcano (94%), bird (94%), and dandelion (93%) distinctly. This finding demonstrates that most middle school students do not associate the concept of technology with natural items. That is, natural phenomena and entities are correctly conceptualized by most middle school students as not being examples of technology. However, natural occurrences of electricity and light, such as lightning, can pose a challenge and be difficult to comprehend for some students (16.3%, as previously noted). Based on our findings, this problem arises and persists among students who primarily associate technology with electricity and light.

Findings Concerning the Second Research Question

We also analyzed whether differences exist in the levels of mental models developed by middle school students in relation to technology concepts according to gender. The distribution of mental model drawings and explanations of middle school students in the writing-drawing activity indicate that female students' drawings and explanations were more detailed than those of male students. The mental model drawings of male students were categorized as simple (28.27%), detailed (61.47%), and unclear/none (9.96%). In the same way, the distribution of mental model drawings of female students was simple (23.72%), detailed (67.98%), and unclear/none (8.30%). These findings indicate that female students tend to provide more detailed mental models than their male counterparts. A similar pattern was also observed in the explanations provided by the participants. Male middle school students had a distribution of mental model explanations that was simple (57.71%), detailed (30.26%), and unclear/none (12.03%). The female students performed better than male students, providing more detailed explanations (simple 53.16%, detailed 35.97% and unclear/none 10.87%) on the concept of technology. This suggests that female students possess more detailed mental models on the concept of technology. Figure 3 illustrates the distribution of dimensions expressed in middle school students' mental models by gender.

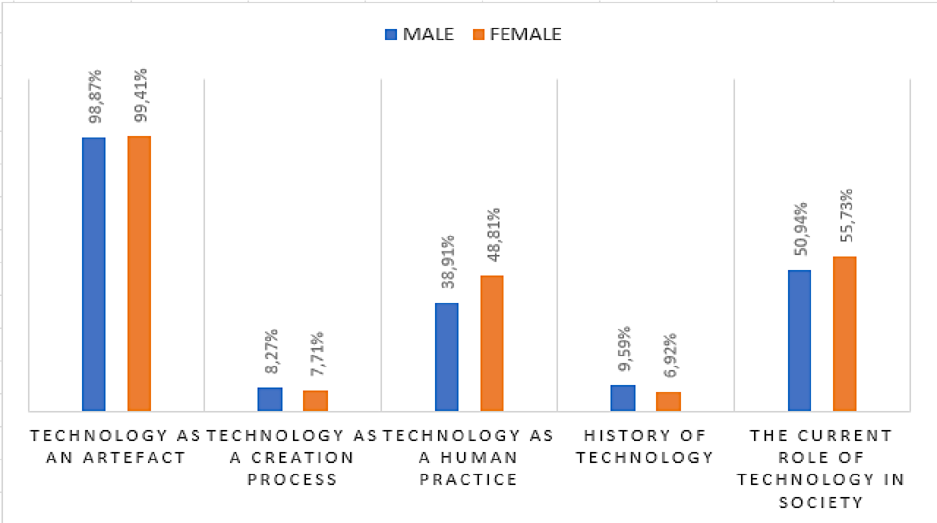

Figure 3. Distribution of the Dimensions Between Male and Female Students

The dimensions of "technology as a human practice" and "the current role of technology in society" were more prominent in the mental models of female students (48.81% and 55.73%, respectively) than in those of male students (38.91% and 50.94%, respectively). However, both genders exhibited similar levels of the dimensions of "technology as an artifact" and "technology as a creation process" in their mental models. The dimension of "history of technology" was more pronounced in the mental models of male students (9.59%) than in those of female students (6.92%). These findings suggest that there may be differences between genders in their perceptions of specific dimensions of technology. While experience and knowledge might impact these differences, female students appear to perceive the interplay between technology, humans, and society more intensely.

When evaluating the mental models of middle school students regarding the concept of technology based on gender, it was found that male students' mental models were rated poor (46.24%), medium (40.04%), and good (13.72%). In contrast, female students' models were significantly better, with medium (45.06%) and good (16.21%) ratings, and significantly lower at the poor level (38.74%). Generally, poor and medium level models were commonly present in both genders. The items specified by male middle school students in the writing-drawing activity were categorized as electrical (92.43%), non-electrical (7.24%), and natural (0.33%) items. The distribution of items preferred by female middle school students also followed a similar pattern: electrical (95.20%), non-electrical (4.52%), and natural (0.28%) items. The majority of male and female middle school students prefer electric items to exhibit their understanding of technology. However, male students favor non-electrical items more than females.

Upon analysis, it was revealed that male students define technology as utilizing mainly electricity or power (78%) and being created by people (78%). Notably, the least favored statement by male students was "must have parts that move" (38.3%), followed by "must have a computer inside" (50.2%). Conversely, female students define technology similarly by primarily selecting these same statements. As it should mostly use electricity or power (78.5%) and should be invented by people (78.9%). In addition, the statement least favored by female students aligns with male students' choices, with "requiring moving parts" (44.9%) followed by "necessitating a computer component" (45.8%). Upon comparing the technology-related statements selected by male and female middle school students, we found a significant statistical difference for the following statements: "must have parts that move" ($t(1036) = 2.132$, $p<0.05$, $d = 0.132$), "must have a screen to look at" ($t(1036) = 2.055$, $p<0.05$, $d = 0.127$), and "must be a thing you can touch" ($t(1036) = 3.840$, $p<0.05$, $d = 0.238$). To further investigate whether the mental model levels regarding the concept of technology differed based on gender among middle school students, the study analyzed the number of correct responses to the WT scale items. The data was normally distributed, and thus an independent t-test was employed to analyze the number of correct answers provided by the students.

There was no statistically significant difference between the scores of male and female middle school students when compared ($t(1036) = 0.757$, $p>0.05$). Furthermore, upon comparing the mean scores of both genders, it was observed that they were nearly identical ($\bar{X}$(male) = 12.18, SD = 3.33; $\bar{X}$(female) = 12.03, SD = 3.06). Based on gender, no statistically significant differences were found in middle school students' correct answer scores on the non-electrical items (t(1036) = 0.784, $p>0.05$), electrical items (t(1036) = 0.558, $p>0.05$), and natural items (t(1036) = -0.683, $p>0.05$) dimensions of the WT scale. The mean of male students ($\bar{X}$(non-electrical) = 3.68, SD = 3.28; $\bar{X}$(electrical) = 4.75, SD = 0.71; $\bar{X}$(natural) = 3.74, SD = 0.70) was not significantly different from the mean of female middle school students ($\bar{X}$ (non-electrical) = 3.52, SD = 3.05; $\bar{X}$ (electrical) = 4.73, SD = 0.69; $\bar{X}$(natural) = 3.77, SD = 0.63). These results suggest that there is no difference about the conceptions of technology between male and female middle school students.

It is evident that male students accurately responded to the non-electrical items dimension with higher correct rates for piano (69%), wind-up toy (57%), and bicycle (45%). Likewise, female students also responded with high rates for piano (70%), wind-up toy (63%), and windmill (42%). It can be concluded that the perception of technology among middle school students of both genders primarily involves moving objects. Low correct rates, however, were observed in male students' responses to items such as sandals (14%), cap (17%), and basket (17%). In contrast, female middle school students had lower scores with items such as basket (13%), sandals (15%), and broom (16%). There were statistically significant differences found in the correct answers given by male and female middle school students in the non-electrical items dimension. Specifically, the items wind-up toy (t(1036) = -2.132, $p<0.05$, d = 0.132), running shoes (t(1036) = 2.667, $p<0.05$, d = 0.165), and bicycles (t(1036) = 2.009, $p<0.05$, d = 0.124) showed significant differences. On the electrical items dimension, both male and female students achieved high scores on items such as game controller (M: 98%, F: 95%), laptop (M: 97%, F: 96%), cell phone (M: 96%, F: 98%), MP3 player (M: 95%, F: 96%), and keyboard (M: 89%, F: 88%). A statistically significant difference was found for the game controller item (t(1036) = -2.132, $p<0.05$, d = 0.132) on this dimension. As for the natural items dimension, both male and female middle school students scored high on Oak tree (M: 94%, F: 96%), volcano (M: 93%, F: 94%), bird (M: 95%, F: 94%) and dandelion (M: 93%, F: 93%). However, a statistically significant difference between male and female students was found only for Oak tree (t(1036) = -2.109, $p<0.05$, $d = 0.130$).

Findings Concerning the Third Research Question

Furthermore, an analysis to investigate whether differences exist at the level of mental models developed by different grade levels was conducted. As shown in Figure 4, the categories of middle school students' mental model drawings and explanations in the writing-drawing activity by grade level.

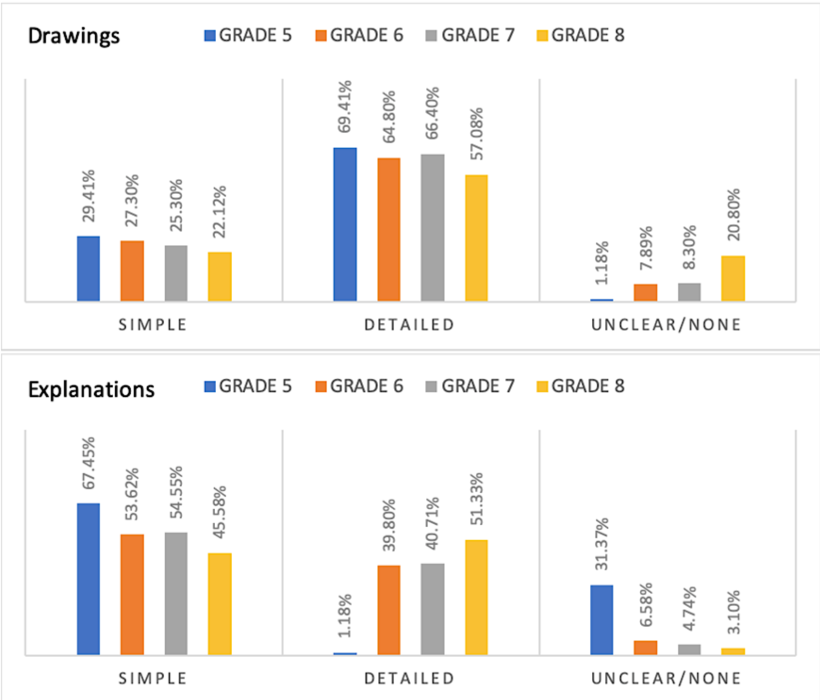

Figure 4. Students' Mental Model Categories According to Grade Level

It is evident that mental model drawings created by 5th grade students had the highest rate of detailed elements (69.41%) and the greatest proportion of the simple category (29.41%) compared to the other grades. However, while the 8th grade students had the highest percentage of the unclear/none category compared to other grade levels, they received the lowest rates in both simple and detailed categories. Additionally, among all grade levels, the 5th grade students had the highest explanation rate (67.45%), but their rate of detailed explanation was unpredictably the lowest (1.18%). Approximately one third of the explanations provided by 5th grade students were deemed unclear or lacking detail. As hypothesized, the proportion of detailed explanations was highest among 8th grade students, with a rate of 51.33%. However, the rates of detailed and simple explanations were similar between 6th and 7th grade students, with slightly higher percentages of detailed explanations among the 7th graders (see Figure 4). These findings suggest that middle school students' mental model explanations become more accurate and detailed as they progress through the grades.

The distribution of dimensions mentioned in the mental models of middle school students is displayed in Figure 5 categorized by grade level. When the results are analyzed, it is evident that the majority of students at each grade level mentioned the "technology as artifact" dimension. Nonetheless, 8th grade students are distinctly set apart from other grade levels in expressing and contacting at significantly higher percentages for all other dimensions. Additionally, we observed that as middle school students progress through higher grades, their percentage of attribution towards dimensions other than "technology as an artifact" also increases. Notably, the dimensions of "technology as an artifact," "technology as a human practice," and "the current role of technology in society" are more prominently expressed in the mental models of middle school students. It seems that middle school students' conceptions of technology are mainly depicted by these three dimensions.

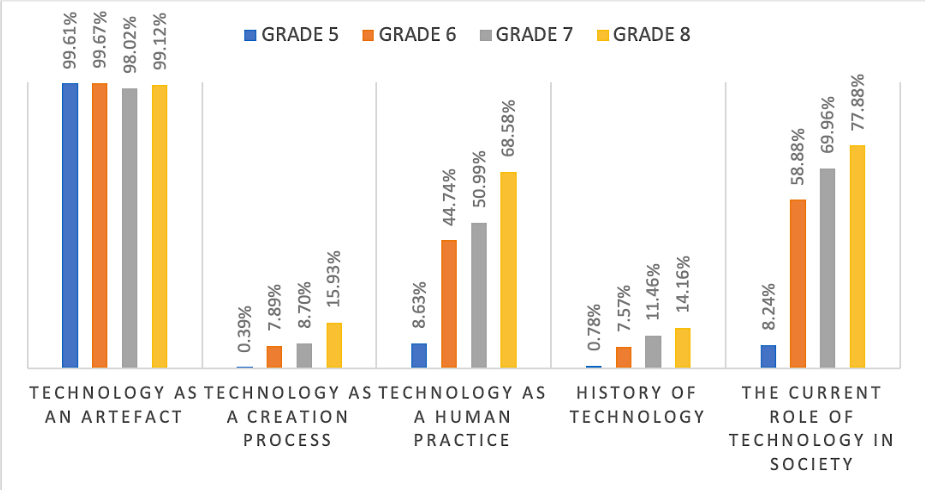

Figure 5. Distribution of the Dimensions According to Grade Levels

When their mental model levels were analyzed based on grade level, a clear indication emerged for fifth graders. Unlike other grades, fifth grade students had a high percentage (88.24%) of poor mental models, as shown in Figure 6. They also received the lowest rates for good (3.92%) and medium (7.84%) mental model levels among all grades. The distribution of mental model levels among 6th and 7th graders indicated a similar pattern (poor 37.17%, medium 45.39%, and good 17.43% for 6th; poor 24.51%, medium 58.50%, and good 17% for 7th). However, 8th graders achieved notably better mental model levels (poor 14.16% and good 26.11%). Surprisingly, while 7th graders had a significantly higher percentage of medium level mental models than 6th graders, they were very close to the medium level of 8th graders (59.73%). As middle school students progress to higher grades, there is a decrease in the percentage of students who have poor mental models, and an increase in their understanding of technology (see Figure 6). With the exception of 5th grade, the mental model levels of middle school students for technology are at a medium level for all other grades.

Figure 6. Middle School Students' Mental Model Levels According to Grade Levels

The distribution of item preferences for different grade levels was consistently similar. For example, in the 5th grade, 95.43% of the preferred items were electrical, 4.41% were non-electrical, and only 0.16% were natural. In the 6th grade, 91.49% of preferred items were electrical, 8.29% were non-electrical, and only 0.22% were natural. Similarly, in the 7th grade, 95.43% of preferred items were electrical, 4.45% were non-electrical, and only 0.12% were natural. Lastly, in the 8th grade, 95.77% of preferred items were electrical, 3.41% were non-electrical, and 0.82% were natural. Upon analyzing the results, it was observed that the majority of students across all grade levels favored the use of electronic items to demonstrate their understanding of technology. Additionally, it was determined that 6th grade students had a greater preference for non-electrical objects compared to other grades, while unexpectedly, 8th grade students demonstrated a higher preference for natural objects than other grades.

Middle school students' responses to the question "Which of these statements define technology?" were analyzed according to the WT scale and grade level. Results suggest that 5th grade students (see Figure 7) rated the following as the most accurate statements describing technology: Technology “must be a computer" (84.5%) and "must be invented by people" (83.1%). In the given survey, 83.6% of 6th grade students favored the descriptive statements of technology such as "must use electricity or power" while 81.3% agreed with the statement "must be a kind of power". Meanwhile, 7th grade students held different conceptions as they mostly agreed with "must be a kind of power" (77.5%) and "must be a thing you can touch" (71.5%). In general, 8th grade students favored the following statements: "must be invented by people" (79.2%), "must use electricity or power" (77.4%), and "must solve a problem" (77.4%). However, except for 7th graders who favored "must have a computer inside" (38.7%), the least agreed statement among 5th (38%), 6th (43.8%), and 8th graders (40.7%) was "must have parts that move".

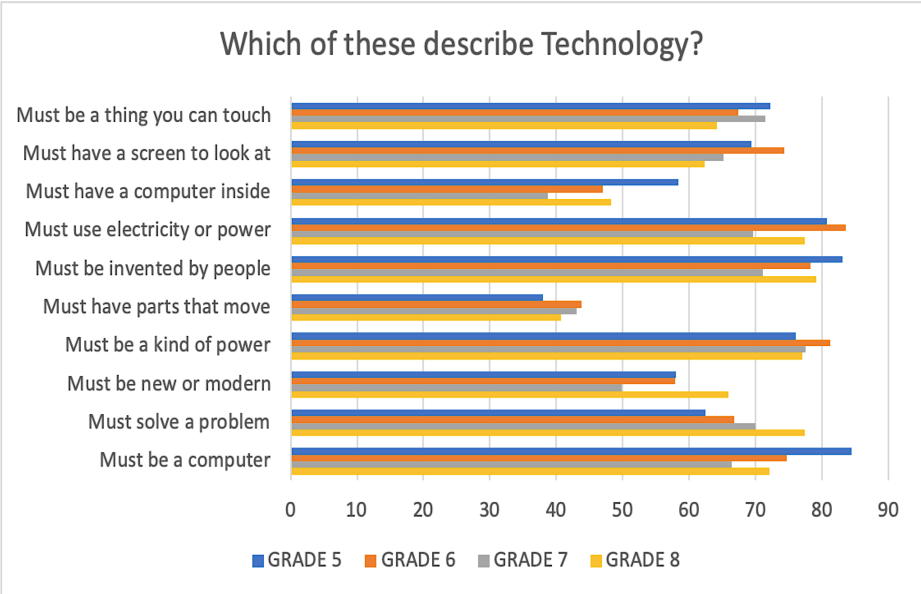

Figure 7. Distribution of the Statements By Grade Levels

A one-way ANOVA test was administered to compare the accurate responses of middle school students on the WT scale items based on their grade levels. The findings indicated a significant variance between grades ($F(3, 1034) = 57.263$, $p = 0.000$, $\eta 2 = 0.1424$), indicating that the grade level has a substantial effect, explaining 14.2% of the variance in the correct answers on the WT scale. This analysis suggests that middle school students' conceptions of technology differ based on their grade level. Post-hoc analysis, utilizing Games-Howell tests, was utilized to compare students from different grade levels. The statistical analysis revealed that a significant difference exists between 5th grade students ($\bar{X}$ = 10.83, SD = 2.48), and 7th ($\bar{X}$ = 13.21, SD = 3.62) and 8th grade students ($\bar{X}$ = 13.61, SD = 3.42). In addition, the results show that there is a significant difference between 6th grade students ($\bar{X}$ = 11.14, SD = 2.30), and 7th and 8th grades. The study found that as students progress through higher grade levels, their accuracy in answering questions related to technology also improves. Notably, 8th grade students demonstrated significantly better performance compared to students in other grade levels. Based on these results, it can be concluded that as the grade level of middle school students increases, their understanding of technology also increases.

To fully address the third research question, we investigated the connections between students' grade levels and WT scale dimensions. The ANOVA analysis revealed that the discrepancies in students' understandings of the scale dimensions were significant. Statistically significant differences were found in the non-electrical ($F(3, 1034) = 50.614$, $p = 0.000$, $\eta2 = 0.128$) and electrical ($F(3, 1034) = 5.820$, $p = 0.001$, $\eta2 = 0.016$) items dimensions, but not in the natural items dimension ($F(3, 1034) = 0.165$, $p>0.05$). These results suggest variations in middle school students' technology conceptions based on their grade levels in the non-electrical and electrical item dimensions. Games-Howell test was used to determine the source of the differences between grade levels. The non-electrical items dimension showed that the 5th grade students ($\bar{X}$ = 2.50, SD = 2.44) scored significantly lower than the 7th ($\bar{X}$ = 4.64, SD = 3.57) and 8th ($\bar{X}$ = 5.02, SD = 3.41) grades. Additionally, there was a statistically significant difference between the 6th grade students ($\bar{X}$ = 2.60, SD = 2.42) and both 7th and 8th grade students. A notable difference was observed in the dimension of electrical items solely among 5th ($\bar{X}$ = 4.58, SD = 0.92), and 6th ($\bar{X}$ = 4.78, SD = 0.61), 7th ($\bar{X}$ = 4.80, SD = 0.62) and 8th grades ($\bar{X}$ = 4.80, SD = 0.56). These findings suggest an increase in conceptions of technology regarding both non-electrical and electrical items among middle school students with higher grade levels. Despite most students correctly identifying natural items as not being examples of technology, we found no significant statistical variance among grade levels. This indicates that most middle school students can successfully identify natural objects as not being related to technology and are capable of effectively conceptualizing natural objects in their perception of technology.

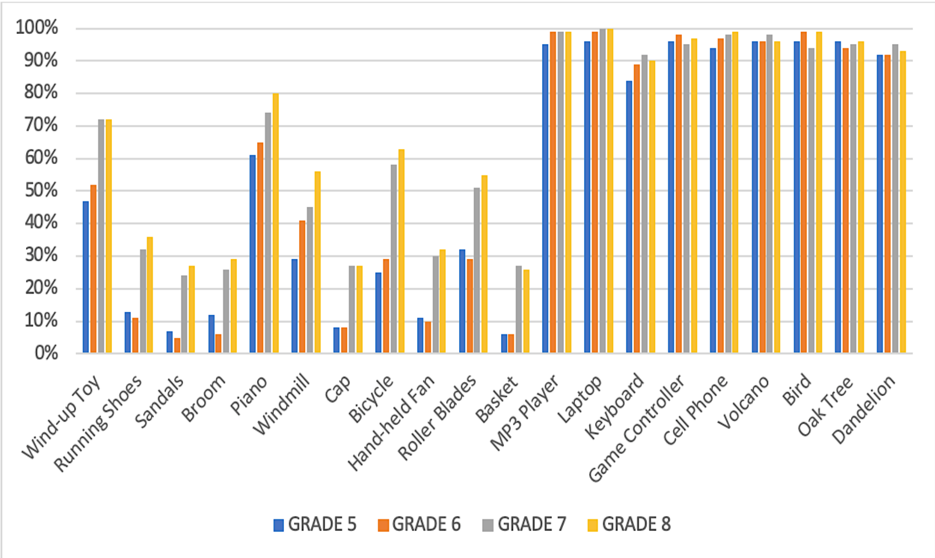

Figure 8. Distribution of Correct Answer Rates by Grade Level

Item-based analysis of middle school students' correct answer ratios by grade level, illustrated in Figure 8, revealed that for the non-electrical items dimension, basket and sandals were the least correctly answered items for all grades. Only 6% and 7% of 5th grade students answered these items correctly. This was also similar for the 6th grade (6% basket, 5% sandals). While the proportion was significantly higher, 7th and 8th grade students responded less accurately to the same items (24% sandals, 26% brooms, 27% basket for 7th grade; 26% basket, 27% sandals, and cap for 8th grade). Conversely, piano was the item with the highest accuracy rate across all grades in the non-electrical items category, ranging from 61% for 5th grade to 80% for 8th grade. In the category of electrical items, the keyboard had the lowest percentage of correct answers ranging from 84% in 5th grade to 92% in 7th grade. However, all other items received much higher percentages, with 95% or more correct answers. In the natural items category, Oak tree and dandelion had the lowest correct answer percentages ranging from 94% to 96%. Nevertheless, correct answer ratios were significantly higher for both electrical and natural items compared to non-electrical items across all grade levels.

DISCUSSION AND CONCLUSION

This study aims to determine middle school students' conceptions of technology through mental models, and whether those conceptions differ based on gender and grade level. The results showed that 64.64% of students' mental model drawings were detailed, while only 33.04% were provided detailed explanations. Thus, middle school students' explanations of their mental models remained simplistic. Consequently, it can be inferred that while elucidating technology through their drawings, students provided a more detailed representation of technology, but employed simpler language to elaborate on the concept. Almost all students highlighted technology as an artifact in the activity. In other words, students' mental models of technology are predominantly represented by electronic products or items like computers, digital tablets, cell phones, televisions etc. Roughly half of the participating students acknowledged the various dimensions of technology as a human practice and its contemporary societal role, whereas they generally lack an understanding of technology as a creative process. Thus, the majority of middle school students did not view technology as a creation process, nor did they conceive technology as a system connecting with the nature of technology. The main reason for this finding can be seen as a result of students experiencing and conceptualizing technology through the devices they use, rather than as applications or systems based on development. Similar findings were reported in Davis et al. (2002) and DiGironimo's (2011) study. It is evident that the number of middle school students who can ascertain more than three nature of technology dimensions is low. Only 6% (four dimensions) and 2% (five dimensions) of students expressed the dimensions effectively. This implies that middle school students may struggle to fully grasp the concept of technology in all its dimensions (DiGironimo, 2011). In our analysis of middle school students' mental model levels on the concept of technology, we found that only 15.90% of students had good comprehension, while 42.48% had medium and 41.62% had low levels. In other words, middle school students have limited understanding about technology and their mental models are mostly at a medium or poor level. Previous studies (e.g., Blom & Abrie, 2021; Davis et al., 2002; İmer Çetin & Timur, 2020; Lachapelle et al., 2019; Liou, 2015; Moreland, 2004; Solomonidou & Tassios, 2007) have also reported findings about students limited understanding about and perception of technology. For example, Liou (2015) reports that high school students usually associate technology with new and electronic devices, while Solomonidou and Tassios (2007) find that 8-12 year old students have limited conceptions of technology and they too associate modern and electronic devices as examples of technology. Blom and Abrie (2021) study also finds that students possess a limited understanding of technology and students view technology primarily as new gadgets and techniques for creating and utilizing them. Likewise, İmer Çetin and Timur (2020) studied middle school students views about technology and they also found that students' understanding of technology is low.

Students usually view technology as tools that make peoples' lives easier. In contrast however, Karaçam and Aydın (2014) attempted to ascertain students' perceptions of technology using metaphors and reported that students' perceptions were mostly positive. Overall, in our study, similar to findings previously reported (Cunnigham et al., 2005; Erişti & Kurt, 2011; Fırat, 2017; Herdem et al., 2014; Jocz & Lachapelle, 2012; Liou, 2015; Lottero-Perdue, 2009), upon analyzing the objects specified by middle school students, it was evident that electronic devices are the most preferred objects associated with technology. It was clear that middle school students associate technology with electronic devices that they use in their everyday life. Our findings on middle school students support the theory that students generally associate the concept of technology with electrical devices.

In our research, we found that 16.3% of middle school students thought that lightning is a technology. Nonetheless, most students were correctly answered the question and explained that lighting is not a technology because it is a natural phenomenon, not produced or made by humans. Clearly, most students (over 83%) have accurate underlying reasoning about lightning is not being a kind of technology. Instead, those students who think that lightning is a type of technology based their underlying conception with electricity and/or light. In other words, some students associate the nature of technology with the concept of electricity and light. This is also evident in Lachapelle et al. (2019) study. The researchers found that except lighting, most children (ages 8-11) correctly categorized the natural items before (over 82%) and after (over 91%) an intervention. They reported that for children (pre 42%), though many of them correctly answered, lighting was confusing and seen as technology (post 54%) even after an intervention. Moreover, in our research, evaluation of middle school students' accurate responses to objects on the scale revealed students success in electrical and natural objects while encountering difficulties with non-electrical ones. Middle school students showed greater proficiency in manipulating non-electronic objects, but struggled with connecting basic objects such as sandals, basket, broom, and cap to technology. Also in our research, we observed that natural phenomena and entities are correctly conceptualized by most middle school students as not being examples of technology. These results also align with the findings of Lachapelle et al. (2019) study. Overall, we conclude that middle school students typically view technology as human-made and capable of solving problems, as well as computerized items and objects that require power and energy to operate. However, natural phenomena involving electricity and light, such as lightning, can be challenging for some students to comprehend. Our research indicates that this difficulty arises among students who primarily associate technology with electricity and light and persists over time. Accordingly, science educators should be vigilant in identifying such students and providing the necessary assistance to improve their understanding of the nature of technology.

The study's second research question explored gender-based differences in middle school students' cognitive representations of technology. Female students (67.9%, 35.9%) exhibited more detailed mental models and explanations, compared to their male counterparts (61.4%, 30.3%), during the writing-drawing activity. Additionally, the findings indicate that female students were more inclined to include the dimension of technology as a human practice (48.8%) and its role in society (55.7%), while male students tended to mention the history of technology more frequently (9.6%). But, both genders demonstrated similar levels for the dimensions, technology as an artifact and as a creation process. The results of the study revealed that there was no significant difference between genders. Therefore, the differences found in these dimensions may be a result of the diversity in students' individual experiences and ideas. When comparing the levels of mental models developed about the concept of technology, we found that female students' models (45% medium and 16.2% good) were considerably better than males (40% medium and 13.7% good). These results may be related to the fact that female students provided more detailed mental model explanations and drawings. Medium and poor level models were also common in both genders. Overall, we did not observe any statistically significant differences between the mean scores of male and female students, nor did we observe any significant differences in the electrical, non-electrical, and natural dimensions of the WT scale. Nonetheless, item-based analysis of the data showed that both groups predominantly favored electrical items. Yet, male students utilized non-electrical (7.24%) items to a greater extent than female students (4.52%). We found significant difference in the correct answers given by male and female middle school students in the non-electrical items dimension. Precisely for the items wind-up toy, running shoes, and bicycles showed significant differences. These findings provide evidence and support the idea that middle school students' conceptions of technology depicted and led by electrical items and moving objects. It is possible that there might be some variations on male and female students' understanding of technology regarding moving objects. Our findings contribute new insight into how middle school students conceptualize the nature of technology. Students need various types of knowledge such as conceptual, procedural, metacognitive and experiential knowledge to understand the nature of technology (Blom & Abrie, 2021). Thus, understanding and distinguishing mechanical simple technologies and applied technologies is often difficult for young students. The study confirmed the findings of previous studies (e.g., Cunningham et al., 2005; DiGironimo, 2011; Jocz & Lachapelle, 2012; Lachapelle et al., 2019; Lottero-

Perdue, 2009; Fırat, 2017) who found that young students do not regard simple mechanical objects or that objects do not use electricity as examples of technological items.

When analyzing middle school students' responses to the question "Is lightning a kind of technology?", we found that the correct answer rates of both male and female students were similar. An examination of the students' descriptions of technology on the scale revealed a gender-based differentiation in the requirement of technology possessing moving parts, a screen to view, and the ability to be touched. There was a slight preference among female students for these descriptions compared to male students. However, when analyzing the correct answer rates of both genders, no statistically significant difference was observed in either the overall scale or sub-dimensions. Therefore, we concluded that, in our sample of Turkish middle school students, male and female participants held similar perceptions of technology. However, conflicting results were reported in other studies whether there is a difference between genders. For example, Rennie and Jarvis (1995a, 1995b) reported that age, gender and previous experiences influenced students' perception of technology. The researchers examined data from 2nd-6th grades in the UK and Australia, and found that Australian girls in 5th and 6th grade were significantly less interested in technology than boys, while British students a small difference was existed in only 6th grades. Others (Herdem et al., 2014; İmer Çetin & Timur, 2020) also reported gender variations and differences on students' understanding and perception of technology. However, some studies (Bulut Özek, 2019; Ergün, 2018; Karaçam & Aydın, 2014) reported similar results with our findings, indicating that there is no gender difference on middle school students' understanding of technology.

When we examined the effects of grade level on middle school students' conceptions of technology, we found clear evidence of variation between grades. While 5th grade students' mental model drawings were more detailed (69.4%) than others, their level of detailed explanation was considerably the lowest (1.18%). However, unlike detailed drawings which was the lowest (57%), 8th grade students' detailed explanation rate was the highest (51.3%). These results lead to the conclusion that while higher grade levels produced more detailed explanations in the activity, their drawings remained at a simpler level. Our results suggest that middle school students' mental model explanations become more accurate and detailed as they progress through the grades. It appears that as students progressed through middle school, they make contact with a greater number of dimensions related to the nature of technology. Furthermore, when mental model levels were analyzed, it was very clear that 5th grade students had the highest level of poor (88.2%) and the lowest level of good (3.9%) mental models. Similar distribution pattern between 6 and 7th grades was observed. Instead, grade 8 students' mental model levels were superior to the others. Overall, except 5th grade, the mental model levels of middle school students' conceptions of technology are at medium level for all other grades. We also found that 8th grade students are distinctly distinguish from other grade levels in expressing and contacting at significantly higher percentages for dimensions of technology. Moreover, we observed that the dimensions of technology as an artifact, a human practice, and the current role of technology in society are obviously expressed in the mental models. It appears that middle school students' have limited conceptions of technology portrayed mainly by these three dimensions. These findings, in line with DiGironimo's (2011) results, provide new insights into exploring how middle school students conceptualize the concept of technology, its application and role in science and society. Recognizing these dimensions and supporting students who have limited understanding of technology is also important for science educators.

Interestingly, however, we found that the distribution of item preferences was consistently similar for all grades. Besides, most students preferred items that work digitally and use electricity to represent their conceptions of technology. Grade 6 students, though unpredictably, had a greater preference for non-electrical objects compared to other grades. Statistical analysis of middle school student responses revealed a significant difference in correct answer rates between grade levels, particularly within the dimensions of electrical and non-electrical items. Overall, the findings show that there is significant difference, and that grade level has a large effect on explaining the middle school students' correct answers. So, it is evident that middle school students' conceptions of technology differ based on their grade level. We observed significant difference between 5th grade students and 7th, and 8th grades (but not with 6th). Likewise, statistically significant difference was found between 6th grade students and 7th, and 8th grades. As hypothesized, 8th grade students demonstrated significantly better performance compared to students in other grade levels. Conclusively, these findings indicate that as the grade level of middle school students increases, their understanding of technology also increases. Previous studies (Davis et al., 2002; Karaçam & Aydın, 2014; Lachapelle et al. 2019; Rennie & Jarvis, 1995a, 1995b) have also reported similar findings. For instance, Karaçam and Aydın's (2014) study, which aimed to determine students' perceptions of technology through metaphors, showed a variation in results depending on the grade level. Davis et al. (2002) examined elementary school children's conceptions of technology and how it changes by grade level (grades 2, 4 and 6). They highlighted the increasing abstract conceptualizations by age and the grade level particularly for 6th grade students. Conversely, Ergün (2018) found no difference on middle school students' perception according to grade level.

Furthermore, we confirmed by item-based analysis that middle school students had difficulties understanding non-electrical items, particularly the items which have non-moving parts. For instance, basket and sandals were the least correctly answered items for all grades. Grade 6 and 5 students correct response rate was same (6%). Though much higher, grade 7 and 8 students were also very close (24-26%). However, correct answer percentages were significantly higher for both electrical and natural items compared to non-electrical items across all grade levels. In this paper, we present clear evidence for the existence of variation between middle school students' grade levels. Furthermore, the findings show that except lighting, these students can successfully identify natural items as not being related to technology. Our findings show that grade level in middle school is not effective in students' associating the concept of technology with natural entities and events. Possibly, experiences in early childhood may lead to a distinction between natural phenomena and students' perception of technology. However, as previously noted, exposure to natural electricity and light may result in a faulty perception of technology for some children. Conducting future research on how technology conception is impacted at younger ages can yield valuable insights.

LIMITATIONS AND IMPLICATIONS

Exploring students' conceptions of technology through mental models is a complex undertaking. While our research designs may have aided in this task, students' mental model expressions may not be entirely comprehensible, and some students may not fully articulate their understanding of the concept. Furthermore, although students may possess an equivalent understanding of the concept, their personal experiences can impact how they articulate and depict their knowledge, resulting in differences in their mental models. Another limitation of the study was that the data was obtained using convenience sampling and survey methods from various schools with comparable student groups; hence, the generalization of findings to all middle school students is limited. Moreover, the WT scale does not account for students' previous knowledge and epistemological perspectives. Studies indicate that students possess varying understandings of scientific concepts, and their prior knowledge and preexisting ideas about technology can influence their capacity to learn new concepts and knowledge (Capobianco et al., 2011; Lachapelle et al., 2019; Jones, 2009). Studies also suggest that students' future learning is affected by their current technological concepts, practices, and processes (Blom & Abrie, 2021; Lachapelle et al., 2019). Therefore, when participants expressed their understanding of technology, their responses may have been limited to their present-day experiences with specific objects. This may explain why objects such as cell phones, computers, and digital tablets frequently emerged from our data.

This study provides an overview of how middle school students comprehend the concept of technology. The findings illustrate the influence of gender and grade level on students' perceptions of technology. However, additional research with varying sample groups is necessary to gather more evidence. It is recommended that future studies examine whether the same outcomes occur across various groups, including different grade levels, socioeconomic statuses, sociocultural backgrounds, and academic levels in different countries. An important implication of these findings is the significance of conducting future research on the influence of technology concepts on children's perception of science and technology, which may yield new insights. Accordingly, it is imperative for science educators to offer the necessary support in enhancing students' comprehension of the nature of technology. In particular, science educators should aid and lead students in advancing their understanding of the nature of technology in relation to basic mechanical and non-electrical items, especially those with stationary components. Therefore, it is crucial for science educators to develop and test various instructional methods that address the dimensions and aspects of technology. Moreover, it is imperative to identify these dimensions and provide support to students who possess limited understanding of technology.

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GENİŞ ÖZET

Giriş

Hem bireysel hem de toplumsal yaşamı önemli ölçüde etkileyen teknoloji, mevcut ve gelecekteki ihtiyaçlarımıza yön veren önemli bir kavramdır. Güncel fen eğitiminde, öğrencilerden teknoloji okuryazarı bireyler olarak teknoloji kavramı ve onun doğası hakkında bilgi sahibi olması, teknolojinin olumlu ve olumsuz etkilerini kavraması, teknolojinin ilerleme sürecini bilim ve teknoloji tarihi açısından öğrenmesi beklenir. Öğrencilerin teknoloji anlayışları, teknolojiyi nasıl algıladıkları ve kullandıkları hakkında çeşitli çalışmalar yapılmıştır (örn., Blom & Abrie, 2021; Bulut Özek, 2019; DiGironimo, 2011; Fırat, 2017; İmer Çetin ve Timur, 2020; Karaçam & Aydın, 2014; Lachapelle vd., 2019; Liou, 2015; Lottero-Perdue, 2009). Teknoloji kavramıyla ilgili daha kapsamlı deneyim ve bilgiye sahip bireyler daha üst düzeyde bir teknoloji anlayışı geliştirebilirler. Ancak, bireylerin deneyim ve bilgilerinin yetersiz kalması durumunda teknoloji anlayışı da daha düşük düzeyde ve sınırlı olarak gelişebilmektedir. Araştırmalar çoğu öğrencinin teknolojik süreçleri kavramakta zorlandığını, teknolojinin sosyal boyutunu ve etkilerini ilişkilendirmekte yetersiz kaldığını göstermektedir (örn., Blom ve Abrie, 2021; Lachapelle vd., 2019). Bu araştırma ise ortaokul öğrencilerinin teknoloji kavramlarını ve anlayışlarını zihinsel modeller aracılığıyla ortaya çıkarmayı ve analiz etmeyi hedeflemiştir. Dolayısıyla, araştırma soruları kapsamında ortaokul öğrencilerinin teknoloji kavramına ilişkin zihinsel modellerinin düzeyleri ve teknoloji anlayışlarının cinsiyet, sınıf düzeyi gibi değişkenler yönünden farklılaşma durumu incelenmiştir.

Yöntem

Araştırma karma yöntem (Creswell & Clark, 2018) deseni ile tasarlanmış, hem nitel hem de nicel veriler eş zamanlı olarak toplanmıştır. Çalışmanın katılımcılarını uygun örneklem metodu ile belirlenen 1038 ortaokul öğrencisi oluşturmaktadır. Öğrenciler, Konya il merkezinde, genel olarak orta sosyoekonomik düzeydeki ailelerin tercih ettiği üç farklı okuldan gelmektedir. Bu çalışmada kullanılan başlıca veri toplama araçları yazma-çizme etkinliği ve "Teknoloji Nedir?" ölçeğidir. Öğrencilerin teknoloji kavramına ilişkin zihinsel modellerini ortaya çıkarmayı amaçlayan yazma ve çizme etkinliğinde, öğrencilere boş bir kağıt verilmiş ve teknoloji kelimesini duyduklarında, okuduklarında akıllarına ne geldiğine ilişkin fikirlerini çizmeleri ve açıklamaları istenmiştir. Öğrencilerin zihinsel model temsilleri ve açıklamaları, Rennie ve Jarvis (1995b) ve DiGironimo (2011) tarafından geliştirilen bir çerçeveye uygun olarak araştırmacılar tarafından oluşturulan dereceli puanlama anahtarı kullanılarak değerlendirilmiştir. Lachapelle vd. (2019) tarafından geliştirilen "Teknoloji Nedir?" ölçeği ise öğrencilerinin teknoloji kavramlarını ortaya çıkarmayı amaçlamaktadır.

Bulgular, Tartışma ve Sonuç

Neredeyse tüm öğrenciler yazma-çizme etkinliğinde teknolojiyi bir 'obje' olarak vurgulamıştır. Diğer bir deyişle, öğrencilerin teknolojiye ilişkin zihinsel modelleri ağırlıklı olarak bilgisayar, dijital tablet, cep telefonu, televizyon vb. elektronik ürünler veya eşyalarla temsil edilmektedir. Ortaokul öğrencilerinin çoğunluğu teknolojiyi bir geliştirme süreci olarak görmemektedir. Davis *vd. (2002) ve DiGironimo'nun (2011) çalışmalarında da benzer bulgular rapor edilmiştir. Öğrencilerin zihinsel model çizimleri ve açıklamaları DiGironimo'nun (2011) teknolojinin beş boyutu temel alınarak analiz edilmiştir. Üçten fazla teknolojinin doğası boyutu tespit edilebilen öğrenci sayısı düşüktür. Öğrencilerin sadece %6'sı (dört) ve %2'si (beş) boyutları tam ilişkilendirebilmiştir. Bu durum, ortaokul öğrencilerinin teknoloji kavramını tüm boyutlarıyla kavramakta zorlanabilecekleri anlamına gelmektedir. Ortaokul öğrencilerinin teknoloji kavramına ilişkin zihinsel model düzeylerini incelediğimizde, teknoji kavramını öğrencilerin yalnızca %15,90'ının iyi, %42,48'inin orta ve %41,62'sinin düşük düzeyde kavradığını tespit ettik. Diğer bir deyişle, ortaokul öğrencilerinin teknolojiye ilişkin kavrayışları sınırlıdır ve zihinsel modelleri çoğunlukla orta veya zayıf düzeydedir. Öğrenciler teknolojiyi genellikle insanların hayatını kolaylaştıran araçlar olarak görmektedir.*

Teknoloji kavramına ilişkin geliştirilen zihinsel modellerin düzeyleri karşılaştırıldığında, kız öğrencilerin modellerinin (%45 orta ve %16,2 iyi) erkeklerden (%40 orta ve %13,7 iyi) daha iyi olduğu görülmüştür. Ancak erkek ve kız öğrencilerin ortalama puanları arasında istatistiksel olarak anlamlı bir fark gözlemlenmemiştir. Erkek ve kız öğrencilerinin elektrikli olmayan nesneler boyutunda verdikleri doğru cevaplar arasında ise anlamlı bir fark bulunmuştur. Sınıf düzeyinin ortaokul öğrencilerinin teknoloji anlayışları üzerindeki etkilerini incelediğimizde ise istatistiksel olarak anlamlı bir farklılık (5. sınıf ile 7. ve 8.; 6. sınıf ile 7. ve 8. sınıf arasında) bulunmuştur. Genel olarak, 5. sınıf hariç, ortaokul öğrencilerinin teknoloji kavramlarına ilişkin zihinsel model düzeyleri diğer tüm sınıflar için orta düzeydedir.

Sonuç olarak, teknolojinin bir obje, bir insan pratiği ve teknolojinin toplumdaki mevcut rolü boyutlarının zihinsel modellerde açıkça ifade edildiğini gözlemledik. Görünen o ki ortaokul öğrencilerinin teknoloji kavramları bu üç boyutla sınırlı kalmaktadır. Bu boyutların farkına varmak ve teknolojiyi sınırlı düzeyde anlayan öğrencileri desteklemek fen eğitimcileri için de önemlidir.

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Contribution of Researchers

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Conflict of Interest

The authors declare that they have no conflict of interest, neither financial nor non-financial.

Ethics Committee Declaration

This study was conducted with the approval of Hacettepe University Ethics Commission dated 28.07.2021and numbered E-35853172-300-00001676756.