

The Effects of Digital Concept Cartoons and Digital Concept Maps on Eliminating Middle School Students' Misconceptions in the Mathematics Course: An Experimental Research

Burcin GOKKURT-OZDEMIR, Hatice YILDIZ-DURAK,
Fatma Gizem KARAOGLAN-YILMAZ, Ramazan YILMAZ

Faculty of Education, Department of Mathematics and Science Education, Bartin University, Turkey
Faculty of Science, Department of Computer Technology and Information Systems
Bartın University, Turkey
e-mail: gokkurtburcin@gmail.com, hatyil05@gmail.com, gkaraoglanyilmaz@gmail.com,
yilmaz04@gmail.com

Received: April 2020

Abstract. The purpose of this study was to investigate the effect of digital concept cartoons and maps in eliminating misconceptions of secondary school students. The research was conducted with 67 students who were studying at three different branches of 7th grade of secondary school. The research was conducted according to semi-experimental design with pre-test, post-test control group, and quantitative and qualitative research methods (mixed pattern) were used together. Accordingly, the mathematics classes in the Study Group I were conducted by the DCC method and the mathematics courses in the Study Group II were conducted by the DCM, and the mathematics courses in the control group were processed by traditional teaching method. In order to determine the students' misconceptions before and after the experiment, Misconception Test was used which was applied as Pre-test and Post-test. In addition, students' opinions and observation processes related to the use of DCC and DCM in mathematics class were included in the experimental process. As a result of the data analysis, there was no statistically significant difference between Study Group I, Study Group II and control group when the results of the Misconception test of the control and study groups were compared. In addition, students stated that the use of DCC and DCM in mathematics course have advantages such as making the courses enjoyable, drawing attention, increasing interest in the course, and visualizing the course topics. In the direction of the findings obtained from the research, various suggestions were made to the teachers and researchers about the use of DCC and DCM in secondary school mathematics courses.

Keywords: digital concept cartoon, digital concept maps, mathematics teaching, misconceptions, secondary school students.

1. Introduction

Concepts in mathematics are very basic components of the teaching and learning processes (Zaslavsky & Shir, 2005). Concepts play an important role in the process of teaching mathematics. Because concepts provide systematic classification of information (Arnaodin & Mintzes, 1985). In mathematics class, it may be difficult to define a concept. To define a concept, it is sometimes necessary to explain the concepts associated with it. For example, in order to define the concept of function, it is necessary to explain the relation concept first. Therefore, in mathematics education, it is expected that the student should be able to build new knowledge on the previous ones. Therefore, it is expected that concepts in mathematics education will facilitate the student's ability to build new information on the previous ones (Ersoy, 2006). For this reason, students may make mistakes and these mistakes may eventually turn into misconceptions.

It can be said that one of the important factors preventing students' conceptual learning is misconceptions (Yenilmez & Yaşa, 2008). The misconception is defined differently by researchers in the literature. Hashweh (1988) defined misconception as immature concepts. Smith, Disessa, and Roschelle (1993) have described the misconception as a "student perception that produces systematic mistakes". The misconceptions are based on the experiences of each student in the past. Therefore, each student's different experiences in his or her own past can lead to different misconceptions (Yenilmez & Yaşa, 2008). Gokkurt Ozdemir, Bayraktar and Yılmaz (2017) stated that the majority of teachers are confused about the misconceptions and the reasons for it. However, it can be said that it is important for the teacher to be aware of these misconceptions and to be able to analyze them well (Zembar, 2008).

When the literature is examined, it is generally seen that studies have been done to determine the misconception (Akkaya & Durmuş, 2006; Bilgin & Akbayır, 2002; Küçük & Demir, 2009; Pesen, 2007, 2008; Şandır, Ubuz, & Argün, 2007). Akkaya and Durmuş (2006) revealed that students did not conceptualize the role of the letters in algebra. Pesen (2008) stated that students' learning difficulties in pointing the fractions on number line and to find out the misconceptions lying behind common mistakes. Similarly, Şandır et. al (2007) revealed that students made many errors in arithmetic operations, in using distributive laws, and in solving equation and inequalities. Adıgüzel et. al. (2018) examined thematically the theses from 2007 to 2017 conducted in Turkey about misconceptions in mathematics education. In this study, it was observed that students had the misconception in each learning area at the secondary school level.

When the study by Adıgüzel *et al.* (2018) is examined, it is seen that the misconception is mostly in the area of learning numbers and operations. When the content of these studies is examined, almost all of the studies are focused on determining the misconception. Türkdoğan, Güler, Bülbül and Danışman (2015), emphasized that the majority of the studies related to misconceptions were focused on the detection of misconceptions and there are limited number of studies focused on removing misconceptions. On the other hand, when studies abroad are examined, it is possible to come up with several studies about the reduction of misconceptions in mathematics education (Karaoglan Yılmaz, Gokkurt Ozdemir & Yasar, 2018; Prescott & Mitchelmore, 2005; Swedosh & Clark, 1997).

Reduction of misconceptions is important for effective mathematics teaching. Because Hewson and Hewson (1984) found that misconceptions affect students' learning negatively. For this reason, it can be said that the teaching strategies that the teachers will use in the learning environments and present to the students and the materials they developed to reduce the misconceptions are important. These materials should enable the students to actively participate in the learning process and to express their ideas easily. There are many teaching materials that serve this purpose, including concept maps and concept cartoons (Gokkurt Ozdemir, 2019). Some techniques are used to reveal those misconceptions. One of the alternative techniques used by teachers is concept cartoons (Naylor & Keogh, 2013). Another tool that is used to reveal what the students know and how their understanding changed in time is, the concept map (Novak, Gowin, & Johansen, 1983). Concept maps need to be rationally integrated to teaching as an effective method for formative assessment and need to be suitable for teachers to use (Hartmeyer, Stevenson, & Bentsen, 2018).

1.1. The Role of Concept Maps in Reducing Misconceptions in the Mathematics Course

Concept maps were first introduced by Joseph Novak in the light of Ausubel's cognitive learning theory. Concept maps are based on expressing the relationships between concepts in a graphical way, allowing students to learn concepts in a meaningful way. Concept maps help students to correct their misunderstandings by enabling them to relate to concepts they already learned. For this reason, it is one of the preferred materials in reducing misconceptions (Ayvacı & Devocioğlu, 2002). Anderson-Inman and Ditson (1999) stated that concept maps have many advantages for students. These advantages are: i) provide students with permanent learning, ii) help students with learning difficulties, iii) allow students to perceive complex structures as a whole, iv) enable teacher to observe students' information about a subject and to identify which student has more difficulty, v) provide the comprehension of the concepts by giving them the opportunity to construct meanings, and vi) have effect on tracking of the student's development from the student file.

Concept maps have been a frequently used teaching material in researches of science education (Kwon & Cifuentes, 2009). Whereas Baki and Mandacı-Şahin (2004) stated that digital concept mapping method can be used as an effective assessment tool in mathematics lessons. Similarly, Kaya (2019) determined that the use of the concept map in the teaching of rational numbers of 7th grade students has a positive effect on students' academic success. Mathematics has a cumulative and spiral structure (Ersoy, 2006), it requires students to understand the relationships between concepts. For example, if the student does not understand the relationship between the concepts of square and rectangle, he or she may misunderstand the definitions of other mathematical concepts such as parallelograms, trapezoids, and misrepresent the hierarchy between them. For this reason, concept maps can be used as an effective teaching material in mathematics courses by showing the relationship between concepts graphically.

1.2. *The Role of Concept Cartoons in Reducing Misconceptions in the Mathematics Course*

The other material that is thought to be effective in reducing the misconceptions is concept cartoon. Concept cartoons can be defined as “the image of the debate that three or more characters make” (Naylor & McMurdo, 1990 as cited in Şengül, 2011). In this discussion, only one of the ideas presented is of scientific acceptance, while the others represent scientifically incorrect ideas (Keogh, Naylor, & Wilson, 1998). The purpose of concept cartoons is to create a discussion environment among students about a concept, situation or event (Uğurel & Morali, 2006).

According to Dabell (2004), concept cartoons have many characteristics. These are: It i) reveals the readiness levels and ideas of the students. ii) Provides a critical approach to thoughts iii) Develops alternative viewpoints and increases motivation. iv) Encourages students as they can defend their ideas over characters. v) Creates a discussion environment. vi) Allows students to self-criticize. vii) helps students to generate new ideas. viii) enables students to overcome the misconceptions. Concept cartoons in science course are frequently used to allow students to question their own and friends’ knowledge and to encourage them to discuss their thoughts in the process and solve problems by using scientific process skills (Duban, 2013; Erdoğan & Özsevgeç, 2012; Kaptan & İzgi, 2014; Tokcan & Alkan, 2013; Uzoğlu *et al.*, 2013). In mathematics course, conceptual cartoons can be used to determine misconceptions, to develop mathematical thinking and to create brainstorming and discussion environments (Sexton, Gervasoni, & Brandenburg, 2009; Uğurel & Morali, 2006; Uğurel, Kesgin, & Karahan, 2013). Yılmaz (2018) was found that the students’ mathematics success in the experimental group, in which 5E model with concept cartoons was used, was higher at .05 significance level than the students’ mathematics success in control group, in which current curriculum was used.

1.3. *Importance of the Study*

Taking these features into consideration, it is thought that the use of both concept cartoons and concept maps in mathematics courses as well as in science courses will allow students to learn mathematical concepts and reduce existing misconceptions. In particular, Digital Concept Maps (DCM) and Digital Concept Cartoons (DCC), which can be prepared with the support of Computer Assisted Instruction (CAI) method which is a more interesting teaching method that attracts the attention of the students, can be effectively used in mathematics courses. For this purpose, concept maps and concept cartoons, which are prepared in an electronic environment, were used in the research to reduce the misconceptions in the learning areas (“Numbers and Operations”, “Algebra”) in which students have misconceptions in mathematics courses. As reasons of the selection of these two areas of learning, it can be shown that the existence of the most misconceptions of the students in these two learning areas. Adıgüzel *et al.*. (2018)

found that secondary school students had the most misconceptions in learning areas of the number and operations. In addition, the fact that “Numbers and Operations” learning area includes the large part of the “Mathematics Teaching Curriculum of the Secondary School” can be shown as one of the reasons for studying this learning area. The “algebra” learning area is also at the center of mathematics learning, since it is associated with many topics of mathematics (Lacampagne, 1995). The language of patterns, symbols, and rules, algebra is among important learning fields of mathematics. That algebra makes itself felt in any area of life makes it obligatory to learn algebra (Williams & Molina, 1997). However; algebra is a course that students have difficulty understanding (Carraher, Schliemann, Brizuela, & Earnest, 2006).

The positive effect of technology on teaching and learning processes related to mathematics a reduction of misconception of students related to mathematics with materials prepared in electronic environment are reasons for using DCM and DCC in research (Karaoglan Yilmaz *et al.*, 2018). Evrekli and Balım (2015) found that the post-test scores of the students in the experiment group using animation-supported concept cartoons were significantly higher than those of the pre-test scores in their studies using animation-supported concept cartoons and only concept cartoons. It can be considered that concept maps or concept cartoons become more complex with computer support during the interpretation and comprehension of the subject or concepts to be taught for the students (Baki & Mandacı-Şahin, 2004). Similarly, it is difficult to design concept cartoons on paper. The purpose of DCMs is to help to teach relationships between concepts by effective videos, pictures, slides, adding notes, bridges between concept map to concept map, voice recordings, web link bridge (Chang, Sung, & Chen, 2001). DCMs offer many advantages such as adaptive and easy content structure, dynamic links, digital communication and digital recording. Rautama (2000) stated that DCMs have many benefits, such as being able to be recorded, printed and changed, make very large concept maps, combine, zoom in and out, and encourage research (as cited in Baki & Mandacı-Sahin, 2004). Akkuş (2013) proved that DCMs are more effective than classical concept maps and have more permanent results for reducing misconceptions. In this context, the facts that DCC and DCM are selected as teaching tools in mathematics courses and used in solving the misconceptions of students reveals the importance of this study.

1.4. Aim of the Study

The aim of this research is to determine the effect of the use of DCC and DCM in the reduction of misconceptions in the learning area of *Numbers and Operations* and *Algebra* in the mathematics course of seventh grade students of secondary school. For this purpose, answers for the following questions were sought:

- a) Is there a statistically significant difference between the scores of misconceptions tests of the control and study groups using traditional teaching methods and DCC, DCM?
- b) What are the opinions of students on the use of DCC and DCM in the course?

2. Method

2.1. Research Model and Study Group

In this research, quantitative and qualitative research methods (mixed pattern) were used together. Concurrent triangulation design was preferred from mixed methods. In this research, this pattern was used to determine the views of 7th grade students about DCM and DCC. According to Creswell and Clark (2008), this pattern is a mixed method pattern in which quantitative and qualitative data related to the same phenomenon are collected and analyzed simultaneously, and the results are integrated and interpreted (See Fig. 1).

Semi-experimental design was used with pre-test-post-test control group in the quantitative dimension, whereas in the qualitative dimension student interviews and observation processes were used. The study group consists of 67 students who took a mathematics course in the seventh grade of a secondary school in the spring semester of the 2016–2017 academic year. Schools where the research was conducted were accepted as socio-economic intermediate level. The distribution of students according to gender and success level in the branches is done by the school administration independently from the research. There are three branches in the seventh grade of the secondary school, where there are 26, 21 and 20 students, respectively. Match-up between branches and study group was determined by random assignment. In the Study group I, mathematical course were processed using digital concept cartoons with 26 students, digital concept maps were used in the Study group II with 21 students, and in the Control group the course was taught by traditional teaching method to 20 students. In the study, the actual names of the participants were kept confidential and the codes were assigned to Study Group I as S1, ... S26, to Study Group II as S27 ... S47 and to Control Group as S48, ... S67.

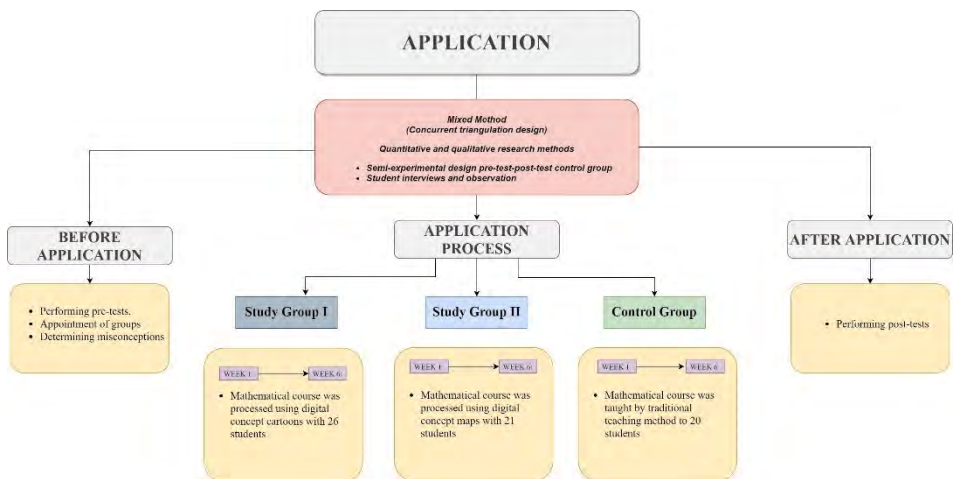


Fig. 1. Research Model.

2.2. Data Collection Tools

Misconception Test: In this study, the “Misconception Test” was applied to the students in the study group at the stage of determining misconceptions they had. In the development of this test, a pool of questions was created by the researchers in order to determine the students’ misconceptions about the two learning areas (numbers and operations, algebra). In the preparation of the questions, only the success related to these two learning areas are considered in the secondary school mathematics curriculum. Because, before the application was done, it was determined that the students had the most misconceptions in these two learning areas by taking into consideration the examination documents of the students and the observation results of the course teacher. For the validity of the study, the opinions of a specialist faculty member in the field of mathematics education and the current mathematics teacher of students were taken. In the direction of expert opinions, the “Misconception Test (MT)” consisting of 60 items has been developed by combining the misconceptions of these two learning areas in the literature and the observations of the mathematics teacher. Due to the high amount of items in the test, MT was applied in 3 class hours to be asked 20 items in one class hour. Prior to the application of MT, the students were informed and explained about this test and sufficient time was given to the students. Examples of questions related to these two learning areas in the MT are presented in Appendix-1.

During the application process, 10 to 15 minutes of informal interviews were conducted by researchers about the answers students gave to the questions in order to clarify students misconceptions or faults. After detecting the misconceptions, digital concept cartoons and concept maps for these misconceptions were prepared. The process of preparing these materials is detailed below.

While success tests were prepared to detect misconceptions, in the first stage, the studies determining the misconceptions in the field of Numbers and Operations and Algebra learning were examined in detail. In addition, unstructured interviews were held with six secondary school mathematics teachers and information about the mistakes their students made in these learning areas in their classrooms was obtained. In the second stage, the Ministry of National Education [MoNE] (2019) in the Middle School Mathematics Curriculum has gained outcomes for both validity areas. The misconceptions in the literature related to these achievements in the third stage (Adıgüzel *et al.*, 2018; Akkaya & Durmuş, 2006; Kaya, 2015; Pesen, 2007, 2008; Soylu & Soylu, 2005; Şandır *et al.*, 2007; Yenilmez & Avcu, 2008; Zembat, 2008) question pools were created for success tests. Achievement tests for the reliability of the research were prepared by the researcher who gave undergraduate courses on misconceptions in mathematics education and had publications on the detection and elimination of misconceptions. The success tests prepared were presented to the opinions of the teachers who conduct the mathematics classes of the classes to be applied and a faculty member who is expert in the misconceptions. In accordance with the opinions of the teachers, the number of questions in the achievement tests has been reduced to 20 on the grounds that the implementation period will not be sufficient. In line with the opinions of the experts, in order to reveal the misconceptions clearly, under each item of the success tests prepared as

multiple choice, “Why did you mark this option? Explain your answer on the grounds. Open-ended questions have been added. In addition, interviews were made with the students’ answers. In this direction, it was tried to identify the students’ errors and errors regarding the question. In cases where the researchers hesitated while analyzing the answers of the students, opinions were received from the mathematics teacher who entered the course of the students.

Semi-structured interviews form: In this study, semi-structured interviews form was used to collect qualitative data. This form was developed by researchers. During the preparation of the form, the opinions of the field experts who had studies on the subject were asked. Questions of the interview form are presented in Appendix-2.

2.3. Designing Digital Concept Cartoons

Mathematics course in Study Group I were processed using DCC. In this context, the preparation of the DCCs has benefited from the website www.tondoo.com. DCC’s have been prepared for each subject in which the misconceptions can be removed by using digital characters, digital scenes and items on the website. DCC-supported mathematics course design was prepared in line with Gagne’s teaching model principles. The Gagne model (Gagné, 1985, 243) was used in the DCC and DCM design process. This model was preferred because it has efficient and easily applicable steps for teachers and students. According to this, Gagne’s teaching model: 1) providing attention and guidance, 2) informing the student about the course objectives, 3) associating the next subject with previous learning 4) presenting the learning content, 5) guiding, 6) revealing performance, 7) providing feedback, 8) assessing performance, 9) the process of ensuring the permanence of the information and strengthening the transfer. DCC’s were prepared for each step in every course and course are processed using these. Among the concept cartoons prepared for this purpose, the ones used at the beginning of the course were mostly prepared to draw attention to subject and to inform the student about the subject and aims, and to remind the previous learning related to the subject. The DCC’s used in later stages of the course were mostly used to initiate discussions about the concept or event, to encourage student to make research, to create a discussion environment, to reveal and reduce misconceptions and ambiguities. The DCC’s used at the end of the course were used to repeat and summarize the learning, to ensure that the learning is valued.

These DCC’s were prepared by three specialists in the field of educational technology using the www.tondoo.com environment. In the preparation of the subject, scope and content of the DCC, a researcher specialized in the field of mathematics education participated. The researcher designed the scenarios, characters, elements and contents of related digital concept cartoons in the paper environment in accordance with Gagne’s teaching stages. These designs were then animated by researchers of educational technology in the environment of www.tondoo.com and DCC’s were prepared. The final decision whether DCC’s are suitable for use in mathematics courses was made by examining the last time by a specialist in the field of mathematics education. When the DCC

was found to be inadequate or inaccurate, the mathematics educator researcher and the education technology researcher came together to give the DCC the final form. A sample of the DCC used in the mathematics class is given in Fig. 2.

The cartoon in Fig. 2 is designed to correct the misconception of students who process algebraic expressions by simply ignoring parentheses and constantly making the same mistake or ignoring unknowns and just dealing with numbers. Similarly, Fig. 3 is designed to correct misconceptions of students who make mistakes by performing operations like natural numbers when summing up fractions with unequal denominators.

In the application of digital concept cartoons, the environment was provided for students to discuss the situation given in the cartoon with their friends and discussions were made in the classroom environment. For example, for the cartoon in Fig. 3,



Fig. 2. Digital Concept Cartoon Designed to Reduce the Misconception of Neglecting Parentheses and Variable in Algebraic Expressions.

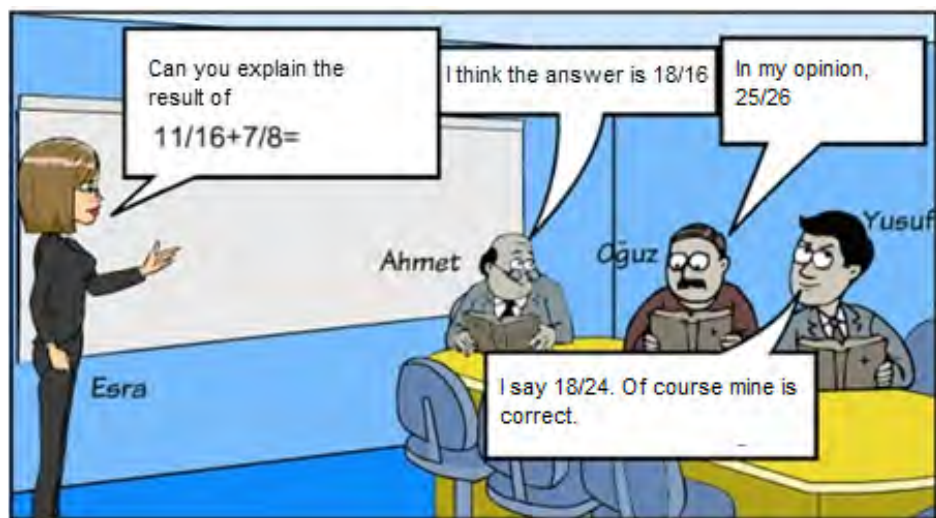


Fig. 3. Digital Concept Cartoon Designed to Reduce Misconceptions Regarding Performing Operations as Natural Numbers in Fractions with Unequal Denominators.

students were asked to share their selection among the answers in the cartoon with the whole class. Later on, the exploration activity was started in which the accuracy of the answers in the cartoons can be tested. Students who selected wrong answer were given transparent fraction cards and were asked to sum up fractions that have unequal denominators. In addition, in order to be able to sum fractions with unequal denominators, they were asked to use area model and the number of it was expected that students should understand that number of parts in the models must be equal to perform operations. In this way, learning environment for the reduction of the misconceptions that students have was presented.

2.4. Designing Digital Concept Maps

Mathematics course in the Study Group II were done using digital concept maps (DCM). In this context, the edraw max program was used for the preparation of DCM. DCM's were prepared for each topic in which misconceptions can be reduced by using digital tools in related website. The design of the mathematics course supported by DCM has been carried out in accordance with Gagne's teaching model principles as well as in the process of preparing the DCCs. In this process, researchers working in the field of education technology and researcher working in the field of mathematics education come together to prepare DCM's to be used in lectures. An example of DCM's used in mathematics class is given in Fig. 4.

Fig. 4, it was designed to correct the misconceptions that students have in understanding meanings of letters that represent variable in the algebraic expressions.

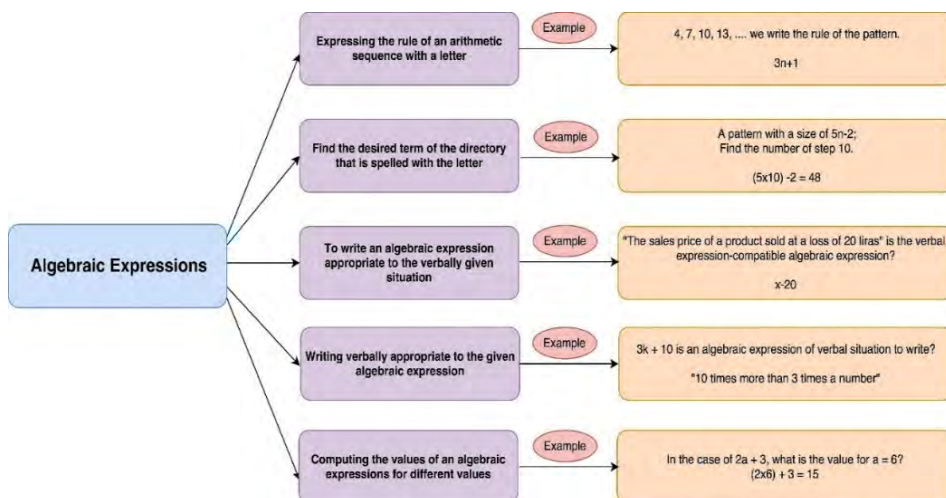


Fig. 4. A Digital Concept Map Designed to Reduce the Misconceptions of Meanings of Variables in Algebraic Expressions.

2.5. Application Process

The application period of this study, which is carried out according to semi-experimental design, lasted a total of six weeks. Before the application process was started, the students in the study group and the control group were subjected to the Misconception Test as a pre-test. The application process was started a week after the test. In the application process, the students in Study Group I received mathematics education supported by DCC, the students in Study Group II received mathematics education supported by DCM, and the students in Control Group received mathematics course with traditional method. DCC and DCMs used in the Study Group I and the Study Group II were reflected with projectors to smart boards in the classrooms to make students think about the concepts, discuss, assess their learning. The misconceptions test was applied as a final test to the students in the study groups and the control groups in the week after the six week application period. Semi-structured interviews were also held with students in order to be able to take the opinions of the students in Study Group I about the use of DCC in mathematics course and the students in Study Group II about the use of DCM in mathematics course. The semi-structured interview form was applied to students face to face. As the questions addressed in a qualitative dimension were questions related to the effectiveness of DCC and DCM, the interview was conducted only with the experimental group.

2.6. Data Analysis

2.6.1. Analysis of Quantitative Data

The reduction of misconceptions of experiment and control groups and its reflection on academic success have been examined quantitatively.

The groups' academic success pre-test post-test scores were compared. ANCOVA analysis was used in the analysis. Prior to the analysis, the assumptions of this test were checked. The normality, kurtosis, skewness coefficients and homogeneity of the data were examined. Assumptions were provided.

2.6.2. Analysis of Qualitative Data

Qualitative data were collected in the study as well as quantitative data. In the process, students were provided to fill out interview forms. Data collected through interview forms were reviewed under the themes and codes. The views of the students were coded by two researchers independently from each other for the reliability of the study using the formula ($\frac{\text{Consensus}}{\text{Consensus}+\text{Dissensus}}$) of Miles and Huberman (1994), and the consistency between encoders was calculated as .94. Two researchers came together and agreed on the remaining 6% difference. In addition, member control was done for the reliability of the research in the coding process.

3. Findings

Obtained findings were presented in two sub-headings: “Findings about Academic Success” and “Findings Related to Student Opinions”.

3.1. Findings about Academic Success

Pre-post test Scores Related to Academic Success of Students

At the beginning of the application period, a pre-test was applied to students’ academic success and to analyze the scores obtained from this test an independent sample t-test was applied. Findings on the pre-test scores of the experimental and control groups are presented in Table 2.

When Table 2 was examined, it was found that the average of pre-experimental academic success scores of the students was 67.86 in the group in which the regular expression was applied and 70.24 after the application. In the experiment groups, the average of pre-application academic success scores in the group using the concept cartoon-designed activities was 66.15, was 68.85 after the application, and in the group using concept maps was 60.25 before the application and 63.75 after the application.

3.2. Post-Test Scores Related to Academic Success According to

Different Methods Applied to Students (DCC, DCM, and Regular Lecture)

One-way covariance analysis (ANCOVA) was used to compare the statistical significant difference between groups’ academic success scores. The results of the ANCOVA on whether there is a significant difference between the post-test scores when pre-test scores of the groups’ academic success were controlled are presented in Table 3.

As seen in Table 3, there is no statistically significant difference between the post-test academic success scores corrected according to pre-test scores of the groups ($F(2 - 61) = .102, p > .05$). In this context, it can be said that the academic success related to reducing the misconceptions of the students did not change significantly depending on the experimental process.

Table 2
Descriptive Findings Pre-test scores of the students of Academic Success

Group	N	Pre-test		Post-test	
		\bar{X}	SD	\bar{X}	SD
Experiment 1	26	66.15	22.28	68.85	21.37
Experiment 2	20	60.25	17.51	63.75	17.31
Control	21	67.86	22.55	70.24	20.34

Table 3
ANCOVA Results of Post-Test Scores of Academic Success According
to Methods Corrected According to Students' Pre-test Scores

Group	\bar{X}	Adj. \bar{X}	Variance Source	Sum of Squares	SD	Squares Avg.	F	p
Experiment1	68.85	67.91	Pre-test	15096.32	1	15096.32	104.42	.00
Experiment2	63.75	67.32	Method	29.59	2	14.79	.102	.90
Control	70.24	68.00	Error	8818.80	61	144.57		
			Total	333500.00	67			

3.3. Findings Related to Student Opinions

Opinions of students about activities that was prepared by digital concept maps and conceptual cartoons in mathematics course and usage of these tools in other subjects, its effects on reducing misconceptions, positive aspects of process have been examined in their interviews. As the interviews with the students report opinions on the subject in more than one subject, number of frequencies does not overlap with the number of students.

Students' Opinions on Activities Made with DCM and DCC in Mathematics Course

Coding frequencies of the codes, the codes under the themes in which students' views on activities designed with digital concept maps and digital concept cartoons in mathematics course were examined are given in Table 4.

When Table 4 is examined, in mathematics course, the most positive opinions of students about the activities designed with digital concept cartoons was related to code enjoyable/funny and for activities designed with digital concept maps positive opinions were related to code attention grabbing ($f = 16$). Most of the students during the interviews found that the activities designed with digital concept maps and digital concept cartoons were interesting because of the fact that they included visuals, and therefore those materials were instructive for them.

In mathematics course, it was seen that the most negative opinions of students about the activities designed with digital concept cartoons were related to code student-level eligibility (difficult/easy). No opinion on the negative aspects of the activities designed with the digital concept map has been reported. Things that were not loved in the process and were thought to negatively affect views were criticisms such as being boring (slow) for some students in the process, usage of common characters in cartoons, interruption of the course flow when characters are used, and problems related to material design (small letters, lack of readability etc.). In this context, some student opinions are as follows:

"I think that the cartoons given to us allow to better understand what we are doing. Because this different kind attracts our attention and makes it more fun and makes our work easier. That's why I think these digital concept cartoons are useful. I also want it to be used more." (S5)

Table 4
Students' Opinions on Activities Designed with DCM and DCC in Mathematics Course

Theme	Code	f
Digital Concept Cartoons		
Positive	Enjoyable / funny	24
	Attention grabbing	15
	Having visual quality	9
	Affect attitude towards the course	8
	Facilitate learning	8
	Detailed / understandable expression	7
	Using digital environment	6
	Use of cartoon	5
	Providing permanent learning	5
	Togetherness of exercise and activity	4
	Reminder of pre-information	3
	Strengthening	3
	Encouraging effort	3
	Relief of students with visuals	2
Negative	Student-level eligibility (difficult / easy)	9
	Boring (slow)	4
	Usage of common characters	3
	Slow pace of the course	1
	Problems related to material design (small letters, lack of readability, etc.)	1
Digital Concept Maps		
Positive	Attention grabbing	16
	Providing permanent learning	8
	Having visual quality	6
	Facilitate learning	5
	Affect attitude towards the course	3
	Enjoyable	2
	Use of digital environment	1
Negative	-	1

“A fun and easy way to understand concepts (digital concept maps). I think it’s pretty good. It aims to improve myself and reduce our shortcomings.” (S31)

“It provides a better understanding of mathematics and is more memorable (digital concept cartoons).” (S17)

Topic titles that Misconceptions were reduced by Students in Mathematics Course with Activities designed with DCM and DCC

Coding frequencies of the codes, the codes under the themes, themes in which students' opinions of students on topic titles that misconceptions were reduced with activities

Table 5

Opinions of Students on Reduction of Misconceptions with Activities Designed with DCM and DCC in Mathematics Course of Students and Topic Titles in which Misconceptions were Reduced

Theme	f	Topic titles	f
Digital Concept Cartoons			
Yes	36	Four operations	12
		Fractions (four operations, simplification, expansion, etc.)	7
		Integers	7
		Absolute value	5
		Decimal numbers	3
		Inequalities/equations/Algebraic Expressions	2
No	21	*	
Digital Concept Maps			
Yes	14	Algebraic expressions	14
No	10	None	

* The students declared that they have knowledge about the subject being taught and that they do not report any topics as there is no misconception.

designed with digital concept maps and digital concept cartoons in Mathematics course were examined are given in Table 5.

According to Table 5, most students expressed that activities designed with digital concept maps and digital concept cartoons reduced most of misconceptions. In addition, when the findings in Table 5 were examined, it was seen that some students stated that they had corrected the mistakes they made in the four operations besides the misconceptions they had. During interviews, they stated that they corrected mistakes in operations such as priority, addition, multiplication, $+/-$ sign change.

In general, it has been seen that most learners had misconceptions in different subjects and that these were corrected by activities designed with DCM and DCC. The opinions of the course teacher involved in the researcher support this situation (See Table 5). Some of the participant's opinions are as follows:

"Yes. About fractions. I learned this subject by reading from the books and watching the activities done. So I knew things in advance. But this year I realized that I had learned wrong information after learning it with digital concepts cartoons." (S10)

"Yes. I could not understand some math topics, like fractions before. But digital concept maps are visually and entirely catchy." (S34)

Liked Aspects by Students in Activities Designed with Digital Concept Cartoons and Digital Concept Maps in Mathematics Course

Table 6 shows the codes and themes under the themes and themes in which students' opinions about the concepts they liked in activities designed with digital concept maps and digital concept cartoons in mathematics course are shown.

Table 6
Liked Aspects by Students in Activities Designed with DCM and DCC in Mathematics Course

Theme	Code	f
DCC		
Aspects related to Digital Concept Cartoons and Environment	visual quality	15
	difficulty of digital concept cartoon content	6
	ease of digital concept cartoon content	4
	facilitate learning	2
	presentation of tips	1
	the sincerity of the learning environment	1
DCM		
Aspects related to Digital Concept Map	Visuals	19
	Enjoyable	7
	Being Holistic	1

According to Table 6, the digital concept cartoon's design features such as color, line, and painting influence student liking. Visual quality is the code that was frequently coded in terms of the most favorable aspects of digital concept cartoon and environment. Difficulty and ease of digital concept cartoon and its facilitation of learning were the favorable aspects. The digital concept map was most liked in terms of visual quality. Students also liked the digital concept map because it shows enjoyable.

There are citations from two students below.

"I mostly like the characters and the visual quality from the activities designed with digital cartoons. Because these cartoons attract my attention more. They make it easier to understand lectures." (S12)

Students' opinions on the use of Digital Concept Maps and Digital Concept Cartoons for other Topics in Mathematics Course

Coding frequencies of the codes, the codes under the themes, themes in which students' opinions of students on use of digital concept maps and digital concept cartoons for other topics in Mathematics course are given in Table 7.

According to Table 7, most students stated that the desire to use digital concept cartoons in other topics is related to the fun of digital concept cartoons and the enjoyment of learning. The digital concept cartoons used in the prepared event made students want to use them in other topics by providing better understanding and permanent learning. However, some students did not want to use the digital concept cartoons in other topics because of the fact that it slows down the course and is boring.

The most frequently coded code among the opinions on the use of the digital concept map in other topics was facilitates learning. On the other hand, since it is appropriate for concept learning, use of it in other topics is also important. Digitality has attracted the interest of students and the fact that the concept map is digital is also important.

Table 7
Students' opinions on the use of DCM and DCC for other Topics in Mathematics Course

Theme	f	Code	f
DCC			
Yes	44	Enjoyable / Learn with fun	16
		Easier understanding with digital concept cartoon	10
		Providing permanent learning	5
		Attention grabbing	5
		Offering a wide range of information opportunities	4
		Desire to see more cartoons	4
No	8	Slow pace of the course	3
		Boring	3
		Disliking selected cartoon	2
DCM			
Yes	26	Facilitate learning	20
		Suitable for concept learning	4
		Being digital	2
No	2	Boring	2

4. Discussion and Conclusion

Findings of this research conducted to reveal the effects of DCC and DCM in reducing the misconceptions in the mathematics courses of middle school students reveal that there is no statistically significant difference between the control and study groups among the results of the concept misconceptions test. However, when student opinions on the use of DCC and DCM in mathematics courses are examined, it is seen that the use of such tools has various benefits. When the literature is examined, it is seen that there is no similar study in which the quantitative findings of this study can be compared. However, it is seen that there are various research results that are in line with the qualitative findings of the research. In the study of Young (2017), it was seen that concept cartoons were effective in diagnosing and eliminating misconceptions in mathematics education. In his qualitative research, Ozdemir, Yildiz-Durak, Karaoglan Yilmaz and Yilmaz (2018) revealed that digital concept cartoon and digital concept map is effective in eliminating misconceptions in mathematics.

The students' positive opinions on the activities using DCC were respectively: making the course enjoyable/funny, grabbing attention, visualizing the course, positively affecting attitudes towards the course, and facilitating learning. Göksu (2014) stated in the study about the use of concept cartoon in topics such as lines, angles, and polygons that learners developed positive opinions about group activities, their curiosity and interest in the courses increased and their learning efforts and desires developed. Erdağ (2011) and Güler (2010) stated that students expressed positive opinions about the use of concept cartoons in teaching mathematics courses. Even if the frequency is low,

students stated that DCC's are not suitable for the student level and the course becomes boring as negative opinions. Considering the success of the students in the misconception test, it is clear that the most efficient subjects that DCC's reduce misconceptions are fractions (four operations, simplification, expansion etc.) and integers. The reason DCC is particularly effective in fractions is related to the fact that the issue is an abstract issue. Thanks to DCC, abstract issues are embodied. This made the teaching of the subject effective.

The students' positive opinions on the activities using DCC were respectively: attention grabbing, providing permanent learning, visualizing the course and facilitating learning. It is noteworthy that these opinions are similar to the opinions of students in the group using DCC. However, it is remarkable that although the opinions like making the course enjoyable/funny, affecting attitude toward the course positively were frequent for the use of DCC's, the students did not comment likewise for the use of DCM's. It is thought that the main reason for this situation is related to the more interest of students in DCM depending on their age levels. When student opinions on the reduction of misconceptions with DCM's were examined, it has been determined that the most effective subject area was algebraic expressions. Students did not report any negative opinion about the use of DCM's. When the literature is examined, it has been seen that the use of DCM and DCC in numerical and intangible courses such as mathematics and science makes the lessons fun, effective and interesting (Young, 2017; Ozdemir *et al.*, 2018). In this respect, it is seen that the results of our research are similar to the literature.

The most favorite aspects of the students about the activities designed with the DCC in the mathematics courses were respectively: the selection of characters that fit the students' interests, visualization of courses, selection of special characters (anime / real, concentration on special characters-Santa Claus etc.), and the use of fun characters. The most favorite aspects of the students about the activities designed with the DCM in the mathematics courses were respectively: visualization of courses, and making courses enjoyable.

The vast majority of students using DCC expressed that DCCs need to be used in other subjects in mathematics courses because of the main reasons such as enjoyable/learning with fun, easier understanding, permanent learning, and grabbing attention. The majority of students using DCM expressed that DCMs need to be used in other subjects in mathematics courses since it facilitates learning.

While the number of researches on the use of DCC and DCM in mathematics education is limited, there are various studies related to other fields such as science in the literature. Kabapinar (2009) found that benefiting from concept cartoons in the reduction of misconceptions in science courses for elementary school students is useful in initiating and sustaining discussions especially on concepts. Similarly, the result of this research which reveals that DCCs are enjoyable, grab attention and increase participation in the course supports this finding. Ekici, Ekici and Aydin (2007) found that concept cartoons are effective tools to reveal and reduction misconceptions in science courses. However, the results of this study show that the use of DCC, DCM

and traditional methods in mathematics does not have a significant difference in misconceptions. It is thought that difference between the result of this research and study of Ekici *et al.* (2007) resulted from the type of course (science/mathematics). Akamca, Ellez and Hamurcu (2009) found that the use of computer-aided concept cartoons in the fourth-grade science course of elementary school led to academic success. It is seen that the results of these studies in the literature differ from the results of this study in terms of reducing misconceptions. Possible reasons for this difference may be that the study was carried out on teacher candidates in science courses. Bolte (1999) found that the use of concept maps have improved the information organization and developed students' mathematical knowledge in the study in which conducted to determine the effectiveness of concept maps in mathematics education. Baki and Mandacı-Sahin (2004) have also shown that DCM can be used as an effective evaluation method in mathematics classes. Hasemann and Mansfield (1995) examined the effectiveness of using concept map in mathematics education and found that concept maps have an important role in learning behaviors and success of students on previous knowledge about some mathematical subjects and determining how they construct relationships between concepts. On the other hand, the study by Wehry and Goudy (2006) emphasizes that concept maps are important tools for teachers in terms of teaching concepts and relationships among concepts in the abstract structure of mathematics. The results related to DCM in the literature are similar to the qualitative findings of this study. However, considering the quantitative findings of our study, it was seen that it does not support the quantitative findings.

It should be agreed that this study have some limitations. First of all, research on mathematics education using DCC and DCM appears to be limited. For this reason, it can be said that similar studies can be useful for the generalization of research results. Secondly, the study was conducted for six weeks with the seventh grade students. Future research may examine the effectiveness of DCCs and DCMs by applying for longer periods and working with students at different grades. Materials developed using DCCs and DCMs were used only with teacher guidance. In future research, the impact of DCCs and DCMs on the learning process and results can be examined by increasing the interaction of students with the mentioned materials outside the school, by applying to schools where each student has a computer or a mobile device. In addition, the effect of using DCCs and DCMs as an evaluation tool can be examined in solving the misconceptions in mathematics. Finally, in addition to the effects of DCCs and DCHs on reducing misconceptions in mathematics, permanence of learning, reduction of cognitive burden, attitude toward lecture and motivation can be examined.

Acknowledgments

This study was funded by Bartın University Scientific Research Project Unit [Grant number 2017-SOS-A-009].

References

- Adıgüzel, T., Şimşir, F., Çubukluöz, Ö., & Gökurt Özdemir, B. (2018). Türkiye’de matematik ve fen eğitiminde kavram yanlışlarıyla ilgili yapılan yüksek lisans ve doktora tezleri: Tematik bir inceleme [Master’s theses and doctoral dissertations on misconceptions in mathematics and science education in turkey: a thematic analysis]. *Bayburt Eğitim Fakültesi Dergisi [Bayburt University Journal of Education]*, 13(25), 57–92.
- Akamca, G. Ö., Ellez, A. M., & Hamurcu, H. (2009). Effects of computer aided concept cartoons on learning outcomes. *Procedia-Social and Behavioral Sciences*, 1(1), 296–301.
- Akkaya, R., & Durmuş, S. (2006). İlköğretim 6–8. sınıf öğrencilerinin cebir öğrenme alanındaki kavram yanlışları [Misconceptions of elementary school students in grades 6–8 on learning algebra]. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi [Hacettepe University Journal of Education]*, 31,1–12.
- Akkuş, G. (2013). *6. sınıf öğrencilerinde dolaşım sistemi konusunda görülen kavram yanlışlarının giderilmesinde bilgisayar destekli kavram haritalarının etkisi [The effects of computer assisted concept map on overcoming 6th grade students’ misconceptions of circulatory system]*. (Unpublished master thesis). Pamukkale University, Denizli, Turkey.
- Anderson-Inman, L. & Ditson, L. (1999). Computer-based concept mapping: A tool for negotiating meaning. *Learning & Leading with Technology*, 26(8), 6–13.
- Arnaodin, M., & Mintzes J. (1985) Students’ alternative conceptions of the human circulatory system: A cross-age study. *Science Education*, 69(5), 721–733.
- Ayvacı, H. Ş., & Devecioğlu, Y. (2002). Kavram haritalarının fen bilgisi başarısına etkisi [Effect of concept maps on science achievement]. Full text paper presented at V. National Science and Mathematics Education Congress (p.62–66). Ankara: ODTÜ, Turkey.
- Baki, A., & Mandacı-Şahin, S. (2004). Bilgisayar destekli kavram haritası yöntemiyle öğretmen adaylarının matematiksel öğrenmelerinin değerlendirilmesi [Assessment of preservice teachers’ mathematical learning through computer aided concept mapping method]. *The Turkish Online Journal of Educational Technology (TOJET)*, 3(2). 91–104.
- Bilgin, T. & Akbayır, K. (2002). Lise 1. sınıf öğrencilerinin ondalık sayıları yorumlama ve uygulamada sahip oldukları kavram yanlışları [The misconceptions that first-year high school students have in interpreting and applying decimal numbers]. *Kastamonu Eğitim Dergisi [Kastamonu Education Journal]*, 10(1), 109–118.
- Bolte, L. A. (1999). Using concept maps and interpretive essays for assessment in mathematics. *School Science and Mathematics*, 99(1), 19–30.
- Chang, K., Sung, Y., & Chen, S. (2001). Learning thorough computer-based concept mapping with scaffolding aid. *Journal of Computer Assisted Learning*, 17, 21–33.
- Creswell, J. W. and Clark, P. L. (2008). *Mixed Methods Reader*. California: Sage Publication.
- Dabell, J. (2004). *The Maths Coordinator’s File-Using Concept Cartoons*. London: PFP publishing.
- Dabell, J. (2008). Using concept cartoons. *Mathematics Teaching Incorporating Micromath*, 209, 34–36
- Duban, N. Y. (2013). Sınıf öğretmenlerinin kavram karikatürlerini hazırlamaya ve kullanmaya yönelik görüşleri [The opinions of primary school teachers about preparing and using concept cartoons]. *Akademik Araştırmalar Dergisi [Journal of Academic Studies]*, 56, 35–54.
- Ekici, F., Ekici, E., & Aydin, F. (2007). Utility of concept cartoons in diagnosing and overcoming misconceptions related to photosynthesis. *International Journal of Environmental and Science Education*, 2(4), 111–124.
- Erdağ, S. (2011). *İlköğretim matematik 5. sınıf dersinde kavram karikatürleri ile destekli matematik öğretiminin, ondalık kesirler konusundaki akademik başarıya ve kalıcılığa etkisi. [The effect of mathematics teaching supported by concepts cartoons on academic achievement and retention in 5th grade classes of primary schools]* (Unpublished master thesis). Dokuz Eylül University, Institute of Education Sciences, Turkey: İzmir.
- Erdogan, A., & Özvegeç, L. C. (2012). Kavram karikatürlerinin öğrencilerin kavram yanlışlarının giderilmesi üzerindeki etkisi: Sera etkisi ve küresel ısınma örneği [The effects of concept cartoons on eliminating students’ misconceptions: greenhouse effect and global warming]. *Turkish Journal of Education*, 1(2), 1–13.
- Ersoy, Y. (2006). İlköğretim matematik öğretim programındaki yenilikler-I: Amaç, içerik ve kazanımlar [Innovations in mathematics curricula of elementary schools-I: Objective, content and acquisition]. *İlköğretim Online [Elementary Education Online]*, 5(1), 30–44.
- Evrekli, E. & Balım, A. G. (2015). Fen derslerinde animasyon destekli kavram karikatürleri kullanımının altıncı sınıf öğrencilerinin sorgulayıcı öğrenme becerileri algılarına etkisi [The effects of concept cartoons assisted animations on 6th grade students’ inquiry learning skills perceptions]. *Western Anatolia journal of Educational Science*, 6(11), 109–136.

- Gagné, R. (1985). *The Conditions of Learning and Theory of Instruction* (4th ed.). Florida-ABD: Holt, Rinehart and Winston, Inc.
- Gökkurt-Özdemir, B., Bayraktar, R., & Yılmaz, M. (2017). Sınıf ve ortaokul matematik öğretmenlerinin kavram yanlışlarına ilişkin açıklamaları [Explanations of primary and middle school mathematics teachers on misconceptions]. *Trakya Üniversitesi Eğitim Fakültesi Dergisi [Trakya University Journal of Education]*, 7(2), 284–305.
- Gokkurt Ozdemir, B. (2019). The use of concept maps and concept cartoons as an assessment tool in teaching and learning Mathematics. S. Çepni & Y. Kara (Eds.). *Current Studies in Educational Measurement and Evaluation*. Ankara: Paradigma Akademi.
- Gokkurt Ozdemir, B., Yildiz-Durak, H., Karaoglan Yilmaz, F.G., & Yilmaz, R. (2018). Use of digital concept cartoons and digital concept maps for elimination of misconceptions in secondary school mathematics course: examination of opinions of teachers. *Proceedings of EDULEARN18 Conference 2nd–4th July, Palma, Mallorca, Spain*Göksu, F. C. (2014). *Doğrular, açılar ve çokgenler konularının kavram karikatür destekli yapılandırmacı öğrenme yaklaşımına göre işlenmesi.*[Teaching the lines, angles and polygons according to constructivism supported by concept cartoons] (Unpublished master thesis). Pamukkale University, Institute of Education Sciences, Turkey: Denizli.
- Güler, H. K. (2010). *Karikatür kullanılarak yapılan öğretimin ilköğretim 6. Sınıf öğrencilerinin matematik dersi doğal sayılar alt öğrenme alanındaki akademik başarılarına ve matematik dersine karşı tutumlarına etkisi.* [Effect of the education with caricatures on academic achievements and attitudes of elementary school sixth grade students towards mathematics course in terms of natural numbers sub-learning]. (Unpublished master thesis). Gazi University Institute of Education Sciences, Turkey: Ankara.
- Hasemann, K., & Mansfield, H. (1995). Concept mapping in research on mathematical knowledge development: Background, methods, findings and conclusions. *Educational Studies in Mathematics*, 29(1), 45–72.
- Hashweh, M. (1988). Descriptive studies of students' conceptions in science. *Journal of Research in Science Teaching*, 25(2), 121–134.
- Hewson, P. W. & Hewson, M. G. (1984). The role of the conceptual conflict in conceptual change and the design of science instruction. *Instructional Science*, 13(1), 1–13.
- Kabapınar, F. (2009). Effectiveness of teaching via concept cartoons from the point of view of constructivist approach. *Colección Digital Eudoxus*, 1(5), 135–146.
- Karaoglan Yilmaz, F. G., Gokkurt-Ozdemir, B., & Yasar, Z. (2018): Using digital stories to reduce misconceptions and mistakes about fractions: an action study, *International Journal of Mathematical Education in Science and Technology*, DOI:10.1080/0020739X.2017.1418919
- Kaptan, F., & İzgi, Ü. (2014). The effects of use concept cartoons attitudes of first grade elementary students towards science and technology course. *Procedia Social and Behavioral Sciences*, 116, 2307–2311.
- Kaya, R. (2015). *Investigation of the 6th Grade Students' Misconceptions about Representations of the Decimal Numbers.* (Unpublished master thesis). Uşak University, Institute of Science and Technology, Uşak.
- Keogh, B., Naylor, S., & Wilson, C. (1998). Concept cartoons: A new perspective on physics education. *Physics Education*, 33(4), 219–224.
- Küçük, A., & Demir, B. (2009). İlköğretim 6–8. sınıflarda matematik öğretiminde karşılaşılan bazı kavram yanlışları üzerine bir çalışma [A study on some misperceived concepts in the teaching of mathematics in 6th–8th grades]. *Dicle Üniversitesi Ziya Gökalp Eğitim Fakültesi Dergisi [Dicle University Journal of Ziya Gökalp Faculty of Education]*, 13, 97–112.
- Kwon, S. Y., & Cifuentes, L. (2009). The comparative effect of individually-constructed vs. collaboratively-constructed computer-based concept maps. *Computers & Education*, 52(2), 365–375.
- Lacampagne, C. (1995). Conceptual framework for the algebra initiative of the national institute on student achievement, curriculum and assessment. In C. Lacampagne, W. Blair, & J. Kaput (Eds.). *The Algebra Initiative Colloquium*, 2, 237–242.
- Miles, M. B. & Huberman, A. M. (1994). *Qualitative Data Analysis: An Expanded Source Book*. Thousand Oaks (CA): SAGE Publications.
- Ministry of National Education [MoNE] (2013). *Matematik dersi (1...8. sınıflar) öğretim programı [Mathematics course (1...8 grades) curriculum]*. Ankara: MoNE
- Pesen, C. (2007). Öğrencilerin kesirlerle ilgili kavram yanlışları [Students' misconceptions of fractions and its effect on solving fractions problems]. *Eğitim ve Bilim [Education and Science]*, 32(143), 79–88.
- Pesen, C. (2008). Kesirlerin sayı doğrusu üzerindeki gösteriminde öğrencilerin öğrenme güçlükleri ve kavram yanlışları [Students' learning difficulties and misconceptions in pointing the fractions on the number line]. *İnönü University Eğitim Fakültesi Dergisi [Inönü University Journal of The Faculty of Education]*, 9(15), 157–168.

- Prescott, A. & Mitchelmore, M. (2005). Teaching projectile motion to eliminate misconceptions. In H. L. Chick & J. L. Vincent (Eds.), *Proceedings of the 29th Conference of the International Group for the Psychology of Mathematics Education*, 4, 97–104.
- Sexton, M., Gervasoni, A., & Brandenburg, R. (2009). Using a concept cartoon to gain insight into children's calculation strategies. *Australian Primary Mathematics Classroom*, 14(4), 24–28.
- Smith, J., Disessa, A., & Roschelle, J. (1993). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *The Journal of the Learning Sciences*, 3, 115–163.
- Soylu, Y., & Soylu, C. (2005). İlköğretim beşinci sınıf öğrencilerinin kesirler konusundaki öğrenme güçlükleri: kesirlerde sıralama, toplama, çıkarma, çarpma ve kesirlerle ilgili problemler [Learning difficulties of 5th class in primary education at fraction: ordering, adding, subtraction, multiplication in fraction and problems related to fraction]. *Erzincan Eğitim Fakültesi Dergisi [Erzincan Journal of Education Faculty]*, 7(2), 101–117.
- Swedosh, P., & Clark, J. (1997). Mathematical misconceptions-can we eliminate them? In F. Biddulf & K. Carr (Eds.), *People in Mathematics Education* (pp. 492–499). Waikato: Mathematics Education Research Group of Australasia.
- Şandır, H., Ubuz, B., & Argün, Z. (2007). 9. Sınıf öğrencilerinin aritmetik işlemler, sıralama, denklem ve eşitsizlik çözümlerindeki hataları [9th grade students' difficulties in arithmetic operations, ordering numbers, solving equations and inequalities]. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi [Hacettepe University Journal of Education]*, 32, 274–281.
- Şengül, S. (2011). Effects of concept cartoons on mathematics self-efficacy of 7th grade students. *Educational Sciences: Theory & Practice*, 11(4), 2291–2313.
- Tokcan, H., & Alkan, G. (2013). Sosyal bilgiler öğretiminde kavram karikatürlerinin öğrenci başarısına etkisi [The effect of the concept cartoons to the students of the social studies teaching]. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi [Ahi Evran University Journal of Kırşehir Education Faculty]*, 14(2), 1–19.
- Türkdogan, A., Güler, M., Bülbül, B. Ö., & Danışman, Ş. (2015). Türkiye’de matematik eğitiminde kavram yanlışlarıyla ilgili çalışmalar: Tematik bir inceleme [Studies about misconceptions in mathematics education in turkey: A thematic review]. *Mersin Üniversitesi Eğitim Fakültesi Dergisi [Mersin University Journal of The Faculty of Education]*, 11(2), 215–236.
- Uğurel, I. & Morali, S. (2006). Karikatürler ve matematik öğretiminde kullanımı [Cartoons and their use in mathematics teaching]. *Milli Eğitim Dergisi [Journal of National Education]*, 170, 32–46.
- Uğurel, I., Kesgin, Ş., & Karahan, Ö. (2013). Matematik derslerinde yararlanılabilecek alternatif bir öğrenme ve değerlendirme aracı: Kavram karikatürü [An alternative learning and assessment tool which can be utilized in mathematic classes ‘concept cartoon’]. *Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü Dergisi [Dokuz Eylül University Journal of Social Sciences Institute]*, 15(2), 313–337.
- Uzoğlu, M., Yıldız, A., Demir, Y. & Büyükkasap, E. (2013). Fen bilgisi öğretmen adaylarının ışıkla ilgili kavram yanlışlarının belirlenmesinde kavram karikatürlerinin ve açık uçlu soruların etkililiklerinin karşılaştırılması [A comparison of effectiveness of concept cartoons and open-ended questions to determine the misconceptions of pre-service science teacher about light]. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi [Ahi Evran University Journal of Kırşehir Education Faculty]*, 14(1), 367–388.
- Wehry, S., & Goudy, L. (2006). Concept mapping in middle school mathematics. <https://www.unf.edu/uploadedFiles/aa/fie/CM-Theory-Methodology-Technology.pdf> [18.11.2017]
- Yenilmez, K., & Yaşa, E. (2008). İlköğretim öğrencilerinin geometrideki kavram yanlışları [Primary school students' misconceptions about geometry]. *Uludağ Üniversitesi Eğitim Fakültesi Dergisi [Journal of Uludag University Faculty of Education]*, 21(2), 461–483.
- Yenilmez, K. & Avcu, T. (2009). İlköğretim öğrencilerinin mutlak değer konusunda karşılaştıkları zorluklar [Primary School Students' Difficulties in Learning Absolute Value]. *Dicle Üniversitesi Ziya Gökalp Eğitim Fakültesi Dergisi [Dicle University Journal of Ziya Gökalp Faculty of Education]*, 12, 80–88.
- Yong, C. L. (2017). Utilizing concept cartoons to diagnose and remediate misconceptions related to photosynthesis among primary school students. In *Overcoming Students' Misconceptions in Science* (pp. 9–27). Springer, Singapore.
- Zaslavsky, O., & Shir, K. (2005). Students' conceptions of a mathematical definition. *Journal for Research in Mathematics Education*, 36(4), 317–346.
- Zembat, İ. Ö. (2008). Sayıların farklı algılanması – Sorun sayılarda mı, öğrencilerde mi, yoksa öğretmenlerde mi? [Perceiving numbers differently – Is the problem with numbers, students or teachers?]. In M. F. Öz-mantar, E. Bingölbali & H. Akkoç (Eds.), *Matematiksel kavram yanlışları ve çözüm önerileri [Mathematical misconceptions and solution offers]* (pp. 41–60). Turkey, Ankara: Pegem Publications.

B. Gokkurt-Ozdemir is an associate professor in the Faculty of Education, Department of Mathematics and Science Education at Bartin University in Turkey. She is interested in instructional technology, pedagogical content knowledge geometry teaching, interactive learning environments, mathematics education.

H. Yildiz Durak is a researcher at Bartin University, Department of Computer Technology and Information Systems. She received his MSc and PhD degrees in Computer Education and Instructional Technologies from Hacettepe and Gazi Universities in 2011 and 2016, respectively. Her research interests consist of Programming training in K12, use of technology in education, flipped learning, e-learning, teacher training, pre-service and in-service training, educational use of social media, digital divide, internet threats, problematic technology use.

F.G. Karaoglan Yilmaz is an associate professor in the Department of Computer Technology & Information Systems at Bartin University in Turkey. She received her B.S. degree from Ankara University, Faculty of Educational Sciences, Department of Computer Education & Instructional Technology (CEIT) in 2008. In 2010, she received her M.A. degree in CEIT from Cukurova University. In 2014, she received her Ph.D. degree in CEIT from Ankara University. She is interested in instructional design and technology, distance education, interactive learning environments, human-computer interaction, virtual reality and augmented reality.

R. Yilmaz is an associate professor in the Department of Computer Technology & Information Systems at Bartin University in Turkey. He received his B.S. degree from Hacettepe University, Faculty of Education, Department of Computer Education & Instructional Technology (CEIT) in 2007. In 2010, he received his M.A. degree in CEIT from Gazi University. In 2014, he received his Ph.D. degree in CEIT from Ankara University. He is interested in educational technology, smart learning environments, technology enhanced learning, virtual reality and augmented reality, human-computer interaction, data mining, learning analytics, eye tracking.

Appendix 1. Example Questions of MT

Questions	Learning Area	Source Used
<p>What is the result of the $12 - 9 \times 8 - 17$</p> <p>A) -27 B) 12 C) -6 D) 27</p> <p>Explain how you solve the question step by step.</p>	Numbers and Operations	Yenilmez & Avcu (2009)
<p>a -5 b 4 c -3</p> <p>What is the result of of the process $a + b - c$?</p> <p>A) 6 B) 2 C) 4 D) -2</p> <p>Explain how you solve the question step by step.</p>		
<p>What is the result of $5 \times 7 - 2 + 15 : 3$?</p> <p>A) 16 B) 38 C) 26 D) 41</p> <p>Explain how you solve the question step by step.</p>		ORME
<p>What is the result of $\frac{11}{16} + \frac{7}{8} \frac{11}{16} + \frac{7}{8}$?</p> <p>A) $\frac{18}{16}$ B) $\frac{25}{16}$ C) $\frac{18}{24}$ D) $\frac{18}{8}$</p> <p>Explain how you solve the question step by step.</p>		Soylu & Soylu (2005)
<p>What is the equivalent of the following: $-(x - 6)$?</p> <p>A) $x - 6$ B) $-x - 6$ C) $6 - x$ D) $x + 6$</p> <p>Can you explain why you think so?</p>	Algebra	ORME
<p>Which of the following is the verbal expression of $4 \left(\frac{x}{7} + 3 \right)$?</p> <p>A) $\frac{1}{4}$ ü of 7 times of sum of 3 with a number</p> <p>B) 4 times of $\frac{1}{7}$ of sum of 3 with a number</p> <p>C) 4 times of sum of 3 with $\frac{1}{7}$ of a number</p> <p>D) $\frac{1}{7}$ Of sum of 3 with 4 times of a number</p> <p>Can you explain why you think so?</p>		

ORME: Observation Results of the Mathematics Educator

Appendix 2. Student Interview Form Questions

A- DCC

1. What do you think about the activities designed with digital concept cartoons used in your math lessons? (Cartoons, writings, visuals etc.)
2. Has there been any mathematical knowledge that you have just learned or previously misunderstood and corrected in the subject explained with activities designed with digital concept cartoons? If your answer is yes, can you write down what information you learned, or what you previously knew and corrected?
3. In events designed with digital concept cartoons, characters, visuality etc. Which one did you liked most? Can you explain why?
4. Would you like to use activities designed with digital concept cartoons on different subjects of mathematics? Please write why?

B- DCM

5. What do you think about the digital concept maps used in your math lessons? (Articles, visuals, etc.)
6. Has there been any mathematical knowledge that you have just learned or previously misunderstood and corrected in the subject explained with digital concept maps? If your answer is yes, can you write down what information you learned, or what you previously knew and corrected?
7. Visuality, shape etc. in digital concept maps. Which one did you liked most? Can you explain why?
8. Would you like to use digital concept maps in different subjects of mathematics? Please write why?