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The Impact of Using Dynamic Mathematics Learning Objects on Pre-Service Mathematics Teachers' Motivation and Cognitive Load Levels

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Abstract

Computer-assisted mathematics education (CAME) continues to be the focus of interest for today's educators. This study aimed to investigate the impact of teaching with dynamic mathematics learning objects (DMLO) in CAME on pre-service mathematics teachers' motivation and cognitive load. The sample of the study, which used an explanatory design, one of the mixed research methods, consisted of 24 pre-service mathematics teachers. The experimental group participated in learning activities with DMLO prepared as part of CAME. The results of the study showed that CAME using DMLO significantly impacted the motivation and cognitive load of pre-service teachers. The visuals and graphics used were evaluated as interesting, fun and engaging by the pre-service teachers. The results were analyzed along with the qualitative data obtained in accordance with the pre-service mathematics teachers' opinions and experiences, and the reasons for the quantitative results were explained. DMLOs can be offered to higher education students taking mathematics courses in different departments of universities. In addition to regular teaching, it may be useful to ensure the use of DMLOs as extracurricular materials through mobile devices.

Keywords: Computer-assisted Mathematics Education, Dynamic Mathematics Learning Objects, Motivation, Cognitive Load

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Dinamik Matematik Öğrenme Nesnelerin Kullanımının Matematik Öğretmen Adaylarının Motivasyon ve Bilişsel Yük Düzeylerine Etkisi

Özet

Bilgisayar destekli matematik eğitimi (BDME) günümüz eğitimcilerinin ilgi odağı olmaya devam etmektedir. Bu çalışmanın amacı BDME'de dinamik matematik öğrenme nesneleri (DMÖN) ile öğretimin matematik öğretmen adaylarının motivasyonu ve bilişsel yükü üzerindeki etkisini araştırmaktır. Karma araştırma yöntemlerinden biri olan açıklayıcı desenin kullanıldığı çalışmanın örneklemini 24 matematik öğretmeni adayı oluşturmaktadır. Deney grubu, BDME kapsamında hazırlanan DMÖN ile öğrenme etkinliklerine katılmıştır. Çalışmanın sonuçları, DMÖN kullanılan BDME'nin öğretmen adaylarının motivasyonunu ve bilişsel yükünü önemli ölçüde etkilediğini göstermiştir. Kullanılan görseller ve grafikler öğretmen adayları tarafından ilginç, eğlenceli ve ilgi çekici olarak değerlendirilmiştir. Sonuçlar, matematik öğretmen adaylarının görüşleri ve deneyimleri doğrultusunda elde edilen nitel verilerle birlikte analiz edilmiş ve nicel sonuçların nedenleri açıklanmıştır. DMÖN'leri üniversitelerin farklı bölümlerinde matematik dersi alan yükseköğretim öğrencilerine sunulabilir. Yüzyüze öğretimin yanı sıra mobil cihazlar aracılığıyla DMÖN''leri ders dışı materyal olarak kullanımının sağlanması faydalı olabilir.

Anahtar Kelimeler: Bilgisayar Destekli Matematik Eğitimi, Dinamik Öğrenme Nesneleri, Motivasyon, Bilişsel Yük

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1. Introduction

The innovations in the field of instructional technologies and the increasing flood of information have made it necessary to use computers as a dominant tool in the learning process where people need and receive more information. Nowadays, computers continue to be used extensively to ensure active participation in learning and teaching processes in educational areas associated with information technologies (IT). Depending on the innovations in information technology, we also witness essential changes and developments in the design of teaching materials. These developments mean that the integration of education and technology is inevitable and requires teachers to adapt more to technology (Özerbaş & Yalçınkaya, 2018).

The necessity of using computers and computer-based technological tools in the educational environment is increasing day by day to make education more efficient, to deal with the increasing complexity of content taught due to the increasing amount of information, to take into account individual needs and new approaches to learning (Gülcü & Alan, 2003; Şataf, 2009; Çelik et al., 2015). IT is considered an effective tool to promote teachers' competence and students' achievement in all educational programs. Based on this, computer-assisted instruction is on the rise, continuing to evolve with each passing day and changing perceptions. (Demirci, 2008; Gülcü et al., 2013). Computers are an essential pedagogical tool for creating an individual learning environment and making knowledge permanent (Kesicioğlu, 2011). With the widespread use of computer technologies in education, multimedia teaching is also widely used (Zhang et al., 2022). Multimedia teaching is considered necessary to motivate students, support lifelong learning, and make the curriculum flexible (Uşun, 2004).

In the literature, multimedia is referred to as educational tools that motivate learners by combining textual elements with images, diagrams, shapes, videos, animations, and sound in learning-teaching activities via IT (Özerbaş & Yalçınkaya, 2018). On this basis, multimedia is believed to increase students' interest and motivation and help develop a positive attitude toward learning by appealing to more than one sensory organ and one type of intelligence (Arslan & Bilgin, 2020). The use of multimedia in the educational environment can arouse students' attention and increase their motivation (Erce, 2021). As the use of multimedia in the learning process simplifies learning, the information becomes more understandable. Multimedia helps to concretize abstract expressions and enables meaningful learning

(Efendioğlu, 2015). Computer-assisted instruction (CAI) applications are also popular because the need for information increases with the introduction of computers into learning environments that usually incorporate multiple media tools. With CAI, students can identify and address their shortcomings on a subject matter by interacting with the computer during the lesson, work in their own time and way by identifying their own learning speed, receive feedback, and see what they have done right or wrong, increase their interest in the lesson thanks to animations, images, sounds, and shapes (Cingi, 2013).

If we consider where CAI is used, computers, considered a tool in education, are used in almost all areas. The use of animations in a spectrum ranging from entertainment to education, from commercials to visual effects is increasing through the proliferation of computer-based instruction (Bağcı & Başaran, 2019; Topçu et al., 2014). The use of web-based games and gamification animations in computer-based education environments is widespread (Solmaz et al., 2018), CAI supports lifelong learning (Sarıtepeci & Orak, 2019), and enables the use of the formal education curriculum outside school boundaries so that individuals can continue their education according to their own pace and interests (Kaleli-Yılmaz & Zengin, 2019).

Studies on computer-based mathematics teaching have gained momentum to provide qualified teaching in mathematics courses where abstract concepts are predominant, based on CAI combining education and technology on a strong foundation (Erce, 2021). Studies report that in mathematics classes, CAME (Computer Assisted Mathematics Education) makes difficult-to-understand and abstract topics more comprehensible, leading to more permanent learning (Gülcü et al., 2013). CAME plays an important role in introducing innovative approaches in mathematics education. For students to easily understand concepts, relationships, algebraic and geometric structures, and algorithms in mathematics, teachers and students often resort to CAME (Herawaty et al., 2019). In mathematics teaching, computer-based materials are used as part of planned instructional activities at appropriate times (Kağızmanlı & Tatar, 2013). In the creation of instructional content, software, i.e., computer-based instructional materials, are used. Software that enables the teaching and learning of mathematics includes computer algebra systems based on processing symbolic expressions (Hohenwarter & Jones, 2007). These systems are designed to make abstract mathematical objects concrete, allowing students to use a variety of senses as they are visual and dynamic (Santi, 2011). Dynamic mathematics learning objects (DMLOs) created using mathematics software can easily convey abstract mathematical concepts, the relationships between them, and the existence of equality. With the introduction of brand-new pedagogical approaches, these tools are now widely used at all levels of education. It is now possible to develop and design DMLOs using Mathematica (Gülcü, 2004), a symbolic mathematics software produced by Wolfram Research. The Mathematica programming language is an object-oriented software with a graphical interface. Dynamic materials created with this software have a positive impact on learning. The use of DMLO's in university mathematics education, where abstract concepts are predominant, aims to provide students with an enjoyable learning process and ensure complete learning by equipping them with permanent and high-level learning skills (Yağcı, 2017).

In higher education, many students encounter problems in mathematical subjects, mostly related to skills requiring abstract thinking (Paridjo & Waluya, 2017). According to Jackson (2008), negative perceptions of learning difficulties in mathematics have an impact on student learning. Attitudes toward mathematics and cognitive abilities impact students' learning of mathematics. Therefore, in addition to arousing positive beliefs and feelings about mathematics competence in students, it can contribute to the understanding of the content by increasing students' interest in the lesson and saving them from having to deal with piles of information (Yağcı, 2017). In this respect, it is possible to enable students to learn mathematics better by increasing their motivation and reducing their cognitive load (Timmerman et al., 2017).

1.1. Theoretical Framework

1.1.1. Learning Motivation and Cognitive Load

One of the important factors affecting the learning process is learning motivation. Studies on motivation define motivation in different ways. According to Emda (2018), motivation is the internal power to continue individual activities. Lin et al. (2018) defined motivation as the effort that sets the direction and magnitude of behavior. Motivation, necessary for behavioral change, is also necessary for learning (Sevinç et al., 2011). Researchers have revealed that highly motivated students are more curious, persistent, determined, excited, diligent, and interested in the learning process compared to low-motivated students (Jong et al., 2017; Süren, 2019). In fact, studies have reported that highly motivated students learn more, want to continue their education and feel better in proportion to their learner traits (Smith et al., 2014). In respect of ensuring students' motivation in the teaching process, plans should be made to increase student motivation while designing the teaching process. Studies emphasize that it is important for students to have high levels of motivation in order to participate effectively in the learning process (Saggaf et al., 2018). The current study analyzed the impact of using DMLOs, based on the CAME method, on students' motivation in mathematics learning.

In addition to its affective effects in the learning process, the CAME method also has an impact on cognitive processes. Cognitive load can be defined as the information density in a student's cognitive systems at any given time (Sweller et al., 2019; Witte et al., 2015; Liao & Lin, 2016). Cognitive load addresses the instructional implications of the limited capacity of human memory and the development of instructional methods that enable students to effectively use their limited information processing capacity (Paas, Renkl & Sweller, 2003). The capacity of working memory is thought to be limited in terms of the amount of information that can be processed and the time in which that information can be stored. When these limits are exceeded, cognitive overload situations occur. The amount of mental resources required for learning can be defined as three basic constructs of cognitive load. These are intrinsic, extraneous, and germane cognitive loads (Leppink & Van der Heuvel, 2015; Liao & Lin, 2016). (1) Intrinsic cognitive load is the mental effort that the task to be performed in a learning environment causes in students' cognitive structures. It depends on the internal structure of the learning task and the learners' prior knowledge about the task. It refers to the amount of information in working memory during the learning process (Vogel-Walcutt et al., 2011; Van Merrienboer & Ayres, 2005). (2) Extraneous cognitive load, occurs, in contrast to internal cognitive load, as a result of unnecessary cognitive activities that are irrelevant to the learning goals, and unnecessary memory effort. External cognitive load is usually caused by poorly planned instructional design (Vogel-Walcutt et al., 2011). (3) Germane cognitive load refers to the basic processing of knowledge to create new knowledge structures (Sweller et al., 2019; Liao & Lin, 2016). It occurs in the process of creating schemas that play an important role in the learning process. In designing the learning process and learning materials, it is important to create a balance these three types of cognitive loads by reducing the roles of the intrinsic and extraneous loads and increasing that of the germane cognitive load. DMLOs have significant potential in terms of reducing students' cognitive load and facilitating an effective learning process by providing students with a multimedia learning environment. On that basis, the current study examined the impact of DMLOs on the cognitive loads of students.

1.2. Related Studies

Along with the developments in computer technologies, there is a burgeoning interest in CAME. Studies argue that the use of dynamic geometry software in the teaching of math subjects positively affects students' learning of geometry (Güven, 2002); that the use of CAME materials has a positive impact on students' attitudes towards mathematics (Baki et al., 2007) besides increasing students' mathematical problem solving skills and improving their approaches to solving mathematical problems (Lazakidou & Retalis, 2010). Studies also show that students exposed to dynamic visual materials exhibit high levels of mathematical self-efficacy, improve their problem-solving skills, and develop a better understanding of concepts and mathematical processes (Kohen et al., 2022). Doğanay and Dinçer (2017) also showed that students who can personalize educational software and use software with learning interfaces are more likely to embrace CAME. Kağızmanlı and Tatar (2012) found in their study on pre-service teachers that CAI with dynamic mathematics software concretizes and visualizes the subject matter and enables students to draw conclusions. Zengin et al. (2013) concluded that pre-service teachers were not only able to learn at their own pace thanks to dynamic math teaching objects such as visualization, facilitation, and concretization, but also that learners found it easier to remember the subject matters while enjoying higher levels of interest in math. Takaci et al. (2015) found in their study that students who used GeoGebra had better learning success in examining functions and drawing charts than students who did not. İliç and Akbulut (2019), in their study examining the effects of different fluency manipulations on learning outcomes, metacognitive assessment, and cognitive load, concluded that fluency manipulations in learning materials lead to better learning success by interfering with fluency, while the use of visual materials increased cognitive load. On the other hand, Lehmann et al. (2016) concluded that visuals with fluency potential used in the learning process facilitated the acquisition of new information by reducing the cognitive load of individuals.

1.3. Rationale and Importance of the Study

Today, it can be argued that approaches to teaching mathematics have changed significantly due to the rapid advances in technology. There is now more focus on the use of cognitive tools that facilitate the learning of math and support the teacher in the teaching process. Instead of taxing the mind, memorizing a lot of abstract information, and subjecting students to tedious procedures, there is emphasis on alternative methods such as CEMA to help students develop mathematical thinking and problem-solving skills. Integrating education and technology, mathematics education strives to grow individuals who can continuously learn, think critically, ask questions, and keep up with innovations and new developments.

Many materials, both print and digital, are used to facilitate learning. The development of computer-based technologies has led to the frequent use of digital learning materials in the classroom. One of the most important digital learning materials is CAI, which involves multiple learning. In this regard, there is a need for DMLO materials in mathematics education where abstract concepts are prevalent (Golezani & Gülcü, 2021). The use of DMLOs in learning environments provides richer learning opportunities by putting the student at the center; it allows students to do and love mathematics, making teaching of mathematics fun, and providing an environment where mathematics can be written and discussed. It is predicted that the use of DMLOs in teaching mathematics on the basis of the method of CAME has multiple effects such as providing an effective learning environment for individuals, achieving an ideal level of learning and motivation to learn, and reducing cognitive load. There is a need for extensive and more studies on this subject at different educational levels. There are studies that examine various variables related to the use of DMLOs in learning at the college level. However, there are a limited number of studies on pre-service mathematics teachers' motivation and cognitive load. In addition, utilization of DMLOs in studies conducted with pre-service teachers, the teachers of the future, may ensure the widespread use of DMLOs at different levels of education.

The objective of this research is to demonstrate the impacts of using DMLOs in math education on pre-service mathematics teachers' motivation and cognitive load. The general objective of this research provides for the investigation of the following sub-objectives:

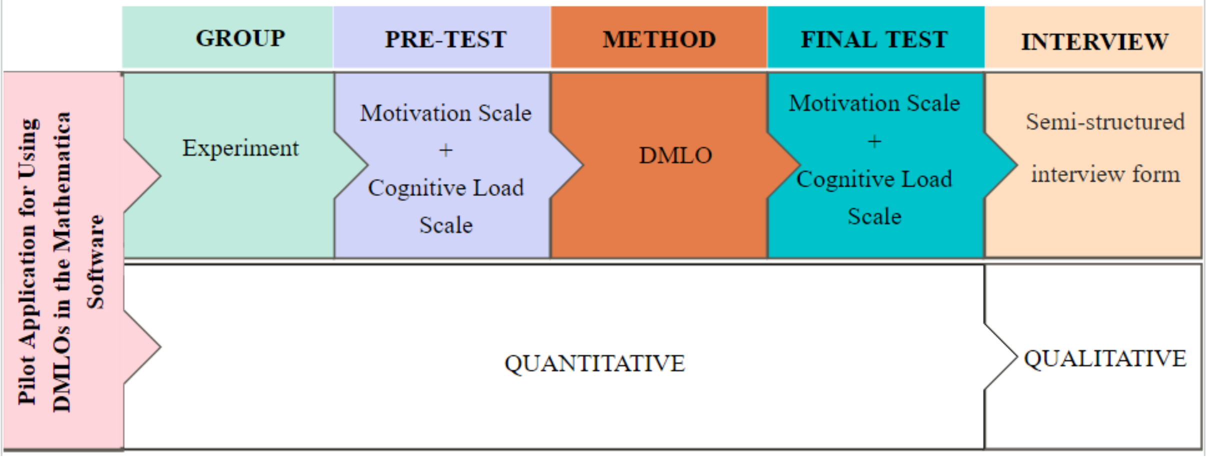
1. Does the use of DMLOs have a significant impact on the motivation of pre-service mathematics teachers?
2. What is the level of cognitive load of pre-service mathematics teachers who used DMLOs?
3. What are the opinions and experiences of pre-service mathematics teachers toward using DMLOs in learning process?

2. Method

For purposes of this study, we employed explanatory design, which is one of the mixed research methods. According to Creswell (2017), mixed methods research is a research approach that involves the use of qualitative and quantitative research methods or paradigms together. With explanatory design, quantitative data are collected firstly, followed by qualitative to explain the quantitative data. Data collected by quantitative and qualitative methods support each other. One of the reasons for choosing the mixed research method is complementation and diversification. Thanks to diversification, a situation examined using the quantitative method can also be examined using the qualitative method and the results are confirmed. In this study, instead of conducting a one-way analysis, we used different methods to obtain more comprehensive results (Yıldırım & Şimşek, 2011).

We determined participants' cognitive load and motivation levels using quantitative methods. Then, we used qualitative methods to analyze and interpret the quantitative variables in detail. For the quantitative aspect of the study, we used a one-group pretest-posttest pre-experimental design. The experimental group had various measurements made before and after the application. The independent variable of the study was DMLO while the dependent variables were pre-service mathematics teachers' motivation and cognitive load level. For the qualitative aspect of the study, we used the case study method to determine the their views on DMLOs. The research model conducted in accordance with the research method was summarized in Figure 1.

Figure 1.
Research process



2.1. Study Group

The study group of this research consisted of twenty-four (thirteen female, eleven male) first-year students enrolled in the Department of Elementary Mathematics Teaching at the Faculty of Education of Siirt University in the 2021-2022 academic year.

We determined the study group by utilizing the purposeful sampling method. All of the pre-service mathematics teachers in the experimental group stated that they were volunteers. Ethics committee permission was also obtained for the study. We informed the pre-service teachers in the experimental group about the process to be carried out within the scope of the course specified in the work schedule in Table 1 and explained the procedures in detail.

Table 1.
Experimental Group's Course Process

	1st Week	2nd Week	3rd Week	4th Week
EXPERİMENTAL GROUP	Training on Mathematica software and information about how to use it Realization of the pilot application Pre-test	Implementation of pre-tests Definite / indefinite integrals with DMLOs, integrals separable into variables Implementation of Cognitive Load Scale at the end of the course.	Remainder calculation, Riemann sum and integrable continuous functions with DMLO Implementation of the Cognitive Load Scale at the end of the course	Integration of rational functions, visual calculation of an integral with DMLO Post-test Conducting interviews for situation assessment

2.2. Research Process

2.2.1. Prior to the Experimental Study

Before starting the application, we made a preparation for the DMLOs to be employed in the process. Expert opinions were sought for the creation of the objects and we decided to use the Wolfram Mathematica 11.0 software package, the license of which belongs to Atatürk University. We opted for materials created using the Mathematica software because they create an interactive environment for students and provide an active learning environment. DMLOs, designed by incorporating expert opinions during the object development phase, needed to be fun, easy to use, user-friendly, include feedback, and be suitable for different learning levels, among other requirements. At the same time, we designed the DMLOs in terms of visuals and content while creating codes in the Wolfram programming language. We designed DMLOs was designed in such a way as to be used flexibly and modified in different ways depending on the student's position in relation to the screen. Designing the visuals in accordance with the level of understanding and comprehension of the concepts facilitated the use of the objects. We designed the DMLOs according to the principles of the theory of cognitive load in multimedia learning. We converted the objects as a ".cdf" extension, to be in the form of an interactive Mathematica file. To use the objects on computers, we used the CDF player, which is offered free of charge by Wolfram. Thanks to this software, the objects can be used on Mac, Windows, and Linux operating systems, regardless of the Mathematica platform. At the same time, installing the CDF file player on the student computers instead of the Mathematica software reduced the workload and made working with the objects more efficient. Another important aspect of the Wolfram technology, namely its taking up as little memory as possible, proved to be an advantage in the experimental environment. In this way, the size of the prepared objects on the diskette was at the KB (kilobyte) level, which eliminated the problems of usage and transportation. We designed the learning objects in such a way that pre-service teachers could eventually use them and transferred them to computers using portable floppy disks. The necessary permissions were obtained for the use of the computer laboratory of the Faculty of Education of the University of Siirt, where the application was to be carried out, and the objects were made available on the computers.

2.2.2. Experimental Study Process

As part of the four-week study, a pilot application was conducted during the first week, and pre-service teachers were informed about the process. Following the pilot training on the use of Mathematica software, pre-service mathematics teachers learned the basic usage functions of Mathematica, how to use integral charts, and how to utilize the dynamic object interface by directly working on objects. In the first week after the training week, the pre-service teachers learnt about definite and indefinite integrals and integrals separable into variables using DMLOs. The theoretical information on the subject was provided by the instructor, and they were introduced to charts/visuals practically by solving practice questions using DMLOs. In the second week, they learned about the development of the theoretical structure of integral calculus via remainder calculation, Riemann sum, and integrability of continuous functions with instructors explaining the subject matter with the help of dynamic charts. During this week, they solved many questions and made comments on various outputs of objects. In the third week, they learned about the integration of rational functions and visual calculation of an integral using dynamic objects and acquired the ability to interpret the integrals using visuals.

We designed the DMLOs in accordance with the subject matter of "Integral" contained in the course Analysis II, taught in the fall semester of the first year at the Faculty of Education, Department of Elementary School Math Teaching. We collected technical and cognitive information, such as the necessary information about the topic and the limitations of the material to be prepared based on the respective course instructor and the standard curriculum set by the Council of Higher Education, and the coding phase was started using Mathematica 11 software. We addressed any shortcomings with the help of expert opinions, and the prepared material was brought to a level that could be used by the pre-service teachers. The pre-service teachers used the mathematics learning objects in the computer laboratory environment on the day specified in the program during the course hours for four weeks. The images related to the use and application of DMLOs in the teaching process during the experiment process are presented in Figure 2 and Figure 3.

Figure 2.
Visuals related to DMOL for Visual Calculation of Area, Riemann Sum and Integral

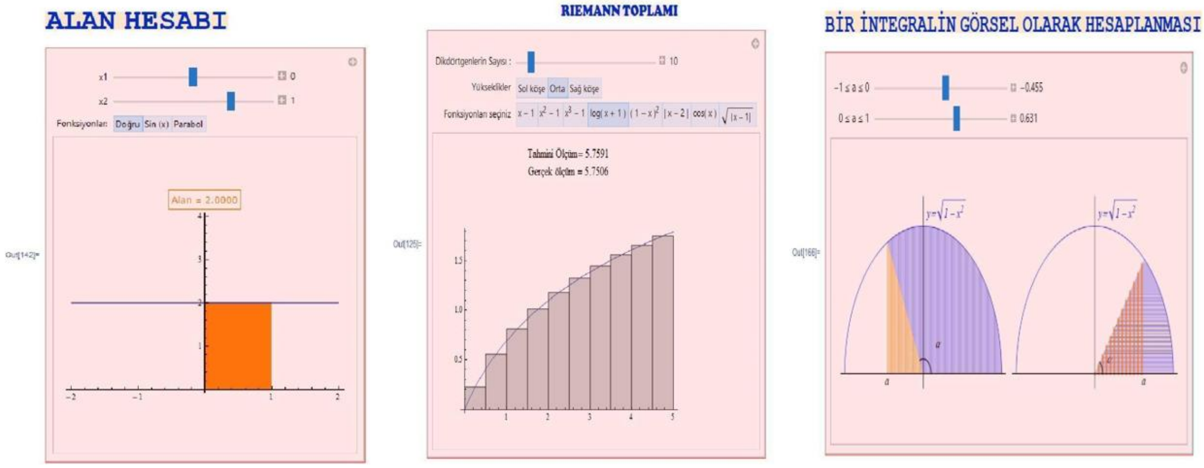


Figure 3.
Images from the experiment process

2.3. Data Collection Tools

2.3.1. Instructional Materials Motivation Scale

We used the "Instructional Materials Motivation" scale developed by Keller (1983) and adapted into Turkish by Kutu and Sözbilir (2011) to determine pre-service mathematics teachers' learning motivation levels towards Mathematics. The 5-point Likert scale consisted of two sub-dimensions, “Attention-Relevance” and “Confidence-Satisfaction”, and twenty-four items. In the Attention-Relevance dimension of the scale, there were items related to arousing the student's curiosity and interest in the lesson and maintaining this interest until the lesson's end and the subject's suitability to the student's personal needs and goals. In the Confidence-Satisfaction dimension of the scale, there were items related to students realizing that they can achieve success with their personal effort and control, and feeling inner satisfaction by rewarding their success with various reinforcers.

There were 19 positive and 5 negative items in the scale. Students were asked to mark the most appropriate option, which would be equal to minimum one and maximum five for each item. The reliability coefficient of the Attention-Relevance sub-dimension of the scale was .79 and the reliability coefficient of the Confidence-Satisfaction sub-dimension was .69. The reliability coefficient obtained from the overall scale was .83.

2.3.2. Cognitive Load Scale

We used the Cognitive Load Scale developed by Dönmez et al. (2022) to reveal the cognitive load levels of the pre-service teachers in the activities carried out during the course. The 5-point Likert scale consisted of 13 items with three dimensions: Intrinsic Cognitive Load, Extraneous Cognitive Load and Germane Cognitive Load. The Intrinsic Cognitive Load dimension of the scale measures learner's cognitive load against the complexity of learning materials based on interaction during the learning process. The Extraneous Cognitive Load dimension includes items related to learning goals that cause the mind to be wasted with unnecessary information. The Germane Cognitive Load dimension includes items related to the creation of schemas for new knowledge structures during the basic processing of information.

There were nine positive and four negative items in the scale. For each item, students were asked to select five if it was the most appropriate for them and one if it was not appropriate at all. The mean value range of the scale items shows that the cognitive load level is "1-1.79 = very low", "1.80-2.59 = low", "2.60-3.39 = medium", "3.40-4.19 = high" and "4.20-5.00 = very high". The reliability coefficient of the intrinsic cognitive load sub-dimension of the scale was .87, the reliability coefficient of the extraneous cognitive load dimension was .81 and the reliability coefficient of the germane cognitive load dimension was .82, and the overall reliability coefficient of the scale was .88.

2.3.3. Semi-structured Interview Form

Within the scope of the research, we conducted semi-structured interviews with six teacher candidates selected from the experimental group at the end of the application process. The researchers prepared a semi-structured interview form and included fourteen questions designed for visuality and feedback about the current and future use of dynamic mathematics learning objects, in order to shed deep light on their views and experiences of the process.

2.4. Data Analysis

We used descriptive analysis, dependent group t-tests, and content analysis in analyzing the data, and the data were analyzed based on the sub-problems of the study. Since the data obtained in the investigation had a normal distribution and met the assumptions of parametric tests, we used parametric tests to analyze the data. For the quantitative aspect of the research, the t-test for dependent groups was used. For the qualitative aspect of the research, we used content analysis to summarize the data from the interviews held with the pre-service teachers at the end of the implementation. Content analysis is an inductive method of analysis based on coding that reveals previously unknown facts underlying the data obtained (Pashakhanlou, 2017). With this type of analysis, data with similar meanings are coded and framed within specific themes and interpreted in a way that the reader can comprehend (Yıldırım & Şimşek, 2013). In the analysis of the data, the data were grouped according to the sub-problems. In the data processing stage, we created codes through content analysis, determined categories to explain the created codes at a general level, and coded students as S1, S2, ... S6, with direct quotes provided. In order to ensure reliability between coders, one researcher firstly analyzed the data and then another researcher analyzed the data to create a common category and code structure.

3. Results

This section includes statistical analysis of the collected data and interpretations of the findings. The findings were presented according to the research questions.

3.1. The Impact of DMLOs on the Motivation of Experimental Group Students

The results of the dependent groups t-test, used to determine whether teaching mathematics with DMLOs has a significant impact on pre-service teachers' motivation were given in Table 2.

Table 2.
Descriptive Analysis Related to Instructional Materials Motivation Scale

	Test	N	M	SD	df	t	p	d
Attention-Relevance	**Pre-Test**	24	2.93	.47	.23	-5.010	.000	.46
	Post-Test	24	3.53	.68				
Confidence-Satisfaction	**Pre-Test**	24	2.98	.56	.23	-5.896	.000	.61
	Post-Test	24	3.73	.41				

Analysis of Table 2 showed that there was a significant difference ($p<.05$) between the pre-test and post-test scores of pre-service teachers in the experimental group from the Instructional Materials Motivation Scale, in both sub-dimensions. In the sub-dimension "Attention-Relevance", mean post-test scores of the experimental group from the Instructional Materials Motivation Scale ($M=3.53$) were significantly higher ($p<.05$) than their pre-test scores ($M=2.93$). In the "Confidence-Satisfaction" sub-dimension, the mean post-test scores of the experimental group from the Instructional Materials Motivation Scale ($M=3.73$) were significantly higher than their mean pre-test scores ($M=2.98$; $p<.05$).

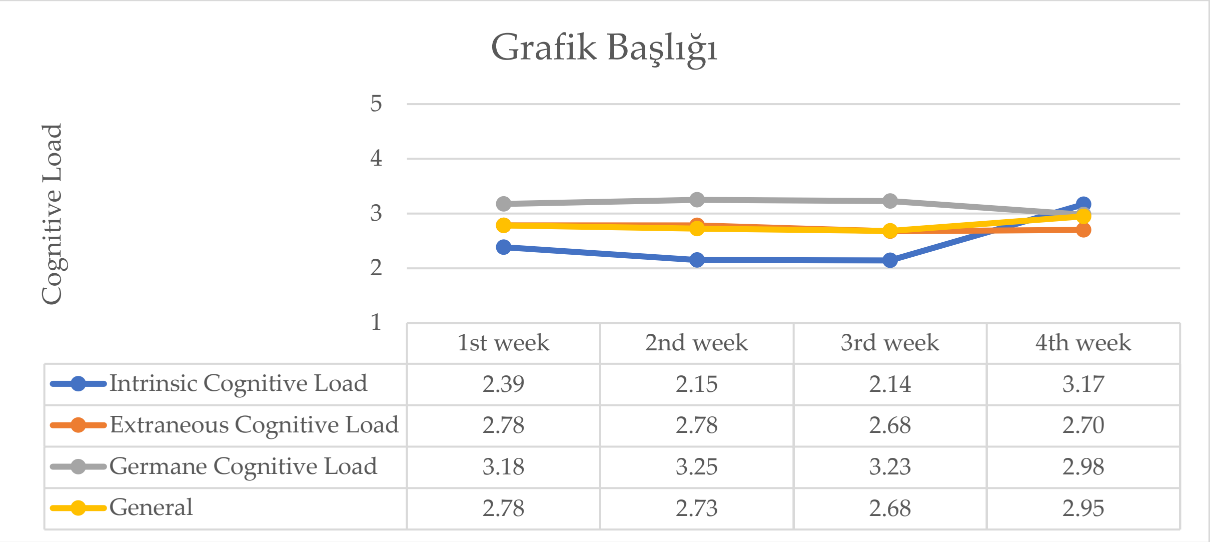
According to the "effect size" developed by Cohen (1988), which indicates whether the difference between the results of the groups in a study is significant or not, the value of the impact size is considered low at 0.20 low, average at 0.50, and high at 0.80. In the case of sub-dimensions, the Cohen's d effect value in the attention-relevance sub-dimension of the study conducted as a pre-post-test was ($d=.46$) while the Cohen's d effect value in the confidence-satisfaction sub-dimension was ($d=.60$). On the basis of this result, we found that the difference between the mean scores of the pre-post tests of the "Attention-Relevance" sub-dimension of DMLOs used in the teaching of integral, a math subject chosen for the application process, had a significant impact close to the mean level in real life. For the confidence-satisfaction sub-dimension, the difference between the means of the pre-post tests had a significant effect at the mean level in real life.

3.2. Cognitive Load levels of Pre-service Teachers

To investigate the impact of teaching mathematics with DMLOs on pre-service teachers' cognitive load, we applied a cognitive load scale to them each week, and the results were reported. The use of DMLOS in mathematics instruction by week and cognitive load scale subdimensions of pre-service teachers and overall scale means were shown in Figure 4.

Figure 4.

Change in Cognitive Load Level by Weekly



Analysis of Figure 4 shows that pre-service teachers' intrinsic cognitive load was low in the first three weeks and medium-high in the fourth week. The germane and extraneous cognitive load was at a medium level from the first week to the last week. As instruction with DMLO continued, the general average of the cognitive load scale was at a medium level throughout all weeks. The weekly averages of the pre-service teachers' responses to the scale items in the experimental period were presented in Table 3.

Table 3

Average of Cognitive Load Scale Items by Weeks

Items	1st Week	2nd Week	3rd Week	4th Week
1. I already knew a few things on this topic. **	2.50	2.14	2.10	3.50
2. I was familiar with the topic. **	2.00	1.95	1.71	4.08
3. My previous knowledge helped me understand the topic. **	2.79	2.45	2.81	3.29
4. The topic was quite strange to me.	2.33	2.05	1.95	1.79
5. Language of instruction was rather vague in this course.	2.71	2.82	2.62	2.92
6. During the course, I could not decide where to focus.	3.04	2.95	2.38	2.88
7. Supplied instructions / explanations were not adequate in this course.	3.08	2.82	3.38	2.92
8. The course environment was unfamiliar to me.	2.63	2.64	2.33	2.42
9. Crucial parts of the course were not clear.	2.46	2.68	2.67	2.38
10. Communication of the course enhanced my desire to learn.	3.25	3.23	3.14	3.17
11. I followed the course with pleasure.	3.04	3.18	3.24	3.17
12. Delivery of the course helped me focus.	3.00	3.36	3.14	3.00
13. I did not find the course interesting. **	3.42	3.23	3.38	2.58

** Marked items were reverse scored.

Table 3 shows that with respect to courses using DMLOs, pre-service teachers had some knowledge in the first week, and previous knowledge facilitated learning and the subject was not unfamiliar to them. In the following weeks, their familiarity with the subject increased, prior knowledge facilitated learning even more and the subject was not unfamiliar. On this basis, it can be argued that pre-service teachers learn the subject easily by using DMLOs and their cognitive load levels decrease.

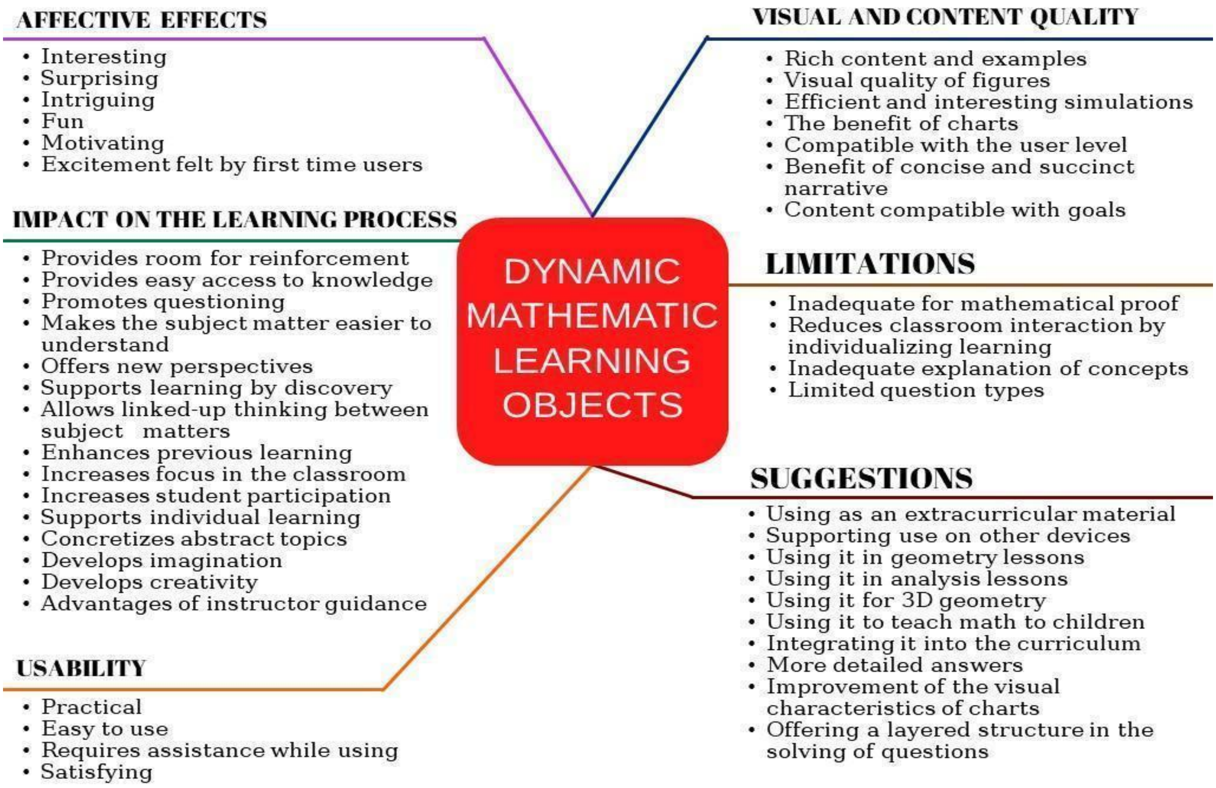
We also established that the mean score of the pre-service teachers from the scale items, were close to each other from the first week to the last week of the application, depending upon the narration of the subject matter, language of expression, focusing on important places and lesson environment when teaching with DMLOs. Therefore, cognitive load levels were also close to each other in this context. The mean score of the pre-service teachers from the scale items from the first week to the last week of the application was at a medium level with respect to the fact that teaching with DMLOs increases the desire to learn, to remain focused throughout lessons and makes them more interesting. In this context, it can be argued that the cognitive load levels were close to each other at a medium level.

3.3. Opinions and Experiences of the Pre-service Teachers

We held semi-structured interviews with six pre-service teachers (3 males and 3 females), randomly selected on a voluntary basis from the experimental group, in order to determine their views on DMLOs. Semi-structured interviews consisting of fourteen questions about their general impression of the process, the tools’ impact on motivation and cognitive load were conducted with pre-service teachers who studied using DMLOs. The categories and codes formed in relation to pre-service teachers' general views on the use of DMLOs in mathematics education were shown in Figure 5.

Figure 5.

Opinions about the Use of DMLOs in Mathematics Education



An analysis of Figure 5 as well as the categories and codes indicate that pre-service mathematics teachers view the use of DMLOs in mathematics instruction from different perspectives. Within the context of their opinions, we created categories such as "Affective Effects," "Ease of Use," "Visual and Content Quality," "Impact of DMLO on the Learning Process," "Limitations," and "Suggestions". The codes and the pre-service teachers' statements belonging to the categories are presented in detail below. Regarding the category of affective effects, we found that pre-service teachers found DMLOs appealing, fascinating, entertaining, and motivating. Below are listed some of the statements:

S1: "It enabled us to bone upon our previous learning, it was good, it aroused curiosity in me."

S2: "Integral was a subject we had already studied in high school. I was very surprised to study it with a computer for the first time."

S3: "It was fun to encounter different examples while increasing and decreasing numbers."

> S2: "Making a difference in the classroom has always been effective with students. The use of such materials via computer had a positive effect on my motivation towards the lesson."

Regarding the usability category, pre-service teachers found the DMLOs useful, easy to use, satisfying while needing help to use them. Below are some of the statements in this context:

> S1: "It was very well to use, I did not encounter any problems."

> S4: "It was easy to use, even though I'm not very computer literate."

> S2: "What the teacher conveyed to us with these materials was very productive."

> S6: "I really liked increasing and decreasing the values in the question."

Regarding the visual and content quality category, pre-service teachers found that DMLOs offered rich content and examples, referring to visual quality of the figures, simulations being efficient and interesting, usefulness of charts, suitability to the user level, concise and succinct narrative, and the content being suitable for the objectives. Below are some of the statements in this context:

> S2: "The material was very good, there were so many examples to reinforce learning. I also found the shapes and figures interesting."

> S5: "I liked the charts and drawings, and I liked studying the changes in charts by increasing and decreasing the numbers. I enjoyed observing the changes with numbers."

> S5: "It attracted my attention because the explanation of the materials was kept short."

> S4: "It was very suitable for university students. I can say that I learned a lot from the material."

Regarding the category of its impact on the learning process, pre-service teachers found DMLOs useful in terms of providing reinforced learning, providing easy access to information, supporting inquiry-based learning, facilitating understanding of the subject, providing different perspectives, supporting learning by discovery, enabling to draw links between subjects, expanding previous learning, increasing attention span in the class, increasing participation, supporting individual learning, concretizing abstract information, promoting imagination, developing creativity and providing instructor guidance. Below are listed some of the statements in this context:

> S1: “It made me refresh my previous learning, it was good, it aroused curiosity in me.”
>
> S4: “Because I first tried to understand things myself in this process, it was an efficient learning process with the teacher's support on this subject, based on me being allowed to question things when learning.”
>
> S5: “Computer assisted instruction was very effective in terms of providing new information and helping me better understand chart reading, which I lacked, and understanding the subject matter.”
>
> S3: “There was no brainstorming in the classroom environment, everyone seemed to be working individually.”
>
> S6: “I think it is necessary to use because it makes abstract information in mathematics concrete through charts.”

Regarding the category of limitations, pre-service teachers found the DMLOs inadequate for mathematical proofs, reducing in-class interaction by individualizing learning, offering insufficient conceptual explanations, and limited question types. Below are listed some of the statements in this context:

> S1: "It is difficult because it is not known where the proof comes from. It's not clear what comes from where."
>
> S3: "Disadvantage of it is.. I think that if it is used continuously in the education process, everyone might become withdrawn in the classroom environment."
>
> S2: "There was not much descriptive explanation, this would be a disadvantage for someone who does not know the subject."

Regarding the suggestions category, pre-service teachers made a number of suggestions with respect to the utilization of DMLOs, including their use as an extracurricular material, supporting their use on different devices, using them in geometry and analysis lessons, and for 3D geometry subjects, using them in teaching mathematics to children, integrating them into the curriculum, making the answers more detailed, improving the visual features of the charts, and providing a progressive structure in solving the questions. Below are listed some of the statements in this context:

> S3: "It was not of a sort that would keep the students very engaged, I think it would be good to use it in their free time."
>
> S5: "It would be a lot better if the answers had been formulated more clearly."
>
> S2: "It would be better if these materials were presented to support formal education. It would have been better if the integral was taught first as part of the regular curriculum and then these materials were used."

4. Discussion and Conclusion

The objective of this study was to determine the impact of the use of DMLOs on pre-service mathematics teachers' motivation and cognitive load in the teaching of integral, which is a subject of mathematics, and to reveal their views on the application. We presented the findings obtained under different headings for each research question, interpreted them and related them to other studies in the literature.

4.1. The Impact of the Use of DMLOs on Pre-service Teachers' Motivation

We found that pre-service mathematics teachers in the experimental group were a lot more motivated, having studied with DMLOs, in comparison to their prior motivational levels. We concluded that the use of DMLOs in the classroom environment increased their motivation towards mathematics. As a matter of fact, the qualitative findings also revealed that they found the use of DMLOs interesting, intriguing, motivating and fun as regards the affective effects of DMLOs. The fact that DMLOs are full of content and elaborate examples, provide a simulation environment, and are easy and convenient to use had a positive impact on pre-service teachers' motivation. There are also other studies that support this finding (Badeleh, 2017; Ben-Abu & Kribushi, 2022; Khoza & Biyela, 2019; Gurevich vd., 2017).

Considering the findings of the study in the context of the sub-dimensions of the instructional materials scale, we found a significant difference between pre and post DMLO pre-service teachers' motivation scores in the attention-relevance sub-dimension. We also found that the attention-relevance sub-dimension had a moderate effect on their motivation. DMLOs used throughout the process were different from the usual teaching methods for students and ensured student participation (Golezani & Gülcü, 2021). Pre-service teachers found the visual charts of DMLOs, adapted to learning content, interesting and so used them satisfactorily (Coştu & Aydın, 2009; Wijaya vd., 2020; Kikas vd., 2020). The qualitative findings of the study also showed that they focused on the lesson better while using DMLOs in mathematics teaching and they found it fit for purpose. In the confidence-satisfaction sub-dimension, we found a significant difference between pre and post motivation scores. We found that the confidence - satisfaction sub-dimension had a moderate impact on pre-service teachers' motivation. The fact that the DMLOs were designed in accordance with the curriculum and that there were exercises and practice questions increased student confidence that they would succeed in this course (Hangül & Üzel, 2010). Presenting the subject content in an understandable way facilitated the learning of the course. Considering the pre-service mathematics teachers' opinions in this context, the association of topics with previous learning facilitated learning and provided reinforcement.

Pre-service teachers who used DMLOs in mathematics teaching were highly motivated, had a positive attitude towards technology and made less effort during the implementation process. We found that pre-service teachers who used DMLOs were inclined to use such tools in their future professional lives and were satisfied with the application. We also noted that learning mathematics using DMLOs increases motivation, and that students enjoy using them and have a positive attitude towards them (Murray & Rabiner, 2014; Schmidt & Vandewater, 2008).

4.2. The Impact of the Use of DMLOs on Pre-service Teachers' Cognitive Load Levels

In this study, computer-supported DMLO represented education-technology integration. We analyzed the cognitive load levels of the pre-service mathematics teachers who studied with DMLOs weekly during the implementation process and found that their cognitive load levels were close to each other and moderate. Looking at the cognitive load in terms of sub-dimensions we concluded that the intrinsic cognitive load sub-dimension was at a low level in the first three weeks, while it was at a medium level in the last week, the extraneous cognitive load sub-dimension was close to a low level throughout the application process, and the germane cognitive load sub-dimension was at a medium level throughout the application process. This result corroborates Sweller (2020) who concluded that media elements such as computers, television, digital games and technology had an impact on cognitive load in the learning process. Learning is easier when both verbal and visual components are used together in the teaching environment (Dinç, 2019; Skulmowski & Xu, 2021). Presenting stimuli such as text and pictures together when it comes to the arrangement of instructional materials enables the use of both channels in working memory. Some studies on computer-assisted learning (Mcgarr & Johnston, 2021; Hu et al., 2019; Sánchez-Pérez et al, 2019) show that two different sources of information do not benefit learning when they are not appropriate for the instructional goal or when they do not facilitate understanding of each other. Attracting students' attention or making them interested in the lesson are considered as important variables in learning. However, it should not be forgotten that the aim of teaching should be to direct the student's interest and attention to the intended learning content rather than to any subject. Looking at the opinions of students regarding cognitive loads with respect to using computer-supported DMLOs in mathematics teaching, quantitative findings support the conclusion that software with a graphical interface facilitates learning and that it is useful to explain the target content in a short and concise way through DMLOs.

4.3. Pre-service Mathematics Teachers' Opinions on the Use of DMLOs

In respect of pre-service mathematics teachers' opinions about the use of DMLOs in mathematics teaching, they had different opinions when it came to their use in the classroom. The reason why pre-service teachers had different opinions was that the individual use of DMLOs had different impacts on pre-service teachers and the use of technology in the educational environment was perceived differently. In addition, in the context of someone using a computer for the first time in the learning process, pre-service teachers were interested in and curious about the use of DMLOs in the educational environment. In support of this finding, Jaakma and Kiviluoma (2019) found that mechanical computer-aided materials attracted students' attention. Regarding the usability of CAI tools, they are easy to use and the help of an instructor is needed while using them. This can be explained by the fact that while using DMLOs in mathematics education, instructor support is needed to explain some formulas.

When we look at the impact of DMLOs on the learning process, there are quite different opinions. Especially in mathematics education, the use of such materials in transferring abstract knowledge is very important for the learning process (Gozelani & Gülcü, 2021). In particular, supporting individual learning and students receiving tutorial support are efficient in terms of gaining abstract knowledge (Aydoğdu et al., 2014; Zengin, 2015). Regarding the visual components and content quality of the DMLOs, pre-service mathematics teachers' opinions show us that multiple learning environments have a significant impact on learning. The fact that the charts used were congruous with the subject matter as a whole and presented in a way to summarize the subject provided satisfaction in terms of use. In addition to the benefits of using DMLOs in mathematics teaching, they also have some limitations for students. In particular, the presence of conceptually inadequate explanations in proving some formulas is considered a limitation for students. Looking at the opinions of students about the use of DMLOs in mathematics education, they recommend their use especially in geometry lessons. Apart from computers, it is also recommended to use them on smart devices such as mobile, tablet, etc. (Hung, 2015; McGivney-Burelle & Xue, 2014).

4.4. Conclusion and Recommendations

This mixed-method study, conducted to examine the impact of using DMLOs in mathematics education on pre-service teachers' motivation and cognitive load, also has some limitations. Among the limitations of the study was the fact that the quantitative part of the study was designed as a one-group pretest-posttest experiment, with a limited sample size. In addition, the fact that the pre-service teachers used the DMLOs only during the course was another limitation of the study.

On the basis of the results of the study, we concluded that the use of DMLOs in teaching the subject matter of integrals was found easy by the pre-service teachers, and that dynamic charts had a positive impact on their motivation levels and kept their cognitive load averages at an optimal level. In this context, it is recommended to repeat such studies with other mathematics subjects containing abstract concepts, besides integral. We concluded that DMLOs had a medium size effect on pre-service mathematics teachers' motivation. The study can be repeated over a longer period and using a larger sample to re-examine the dimension of motivation. In future studies, the impact of DMLOs on pre-service teachers' achievement, motivation and problem-solving skills can be investigated by using them for a longer period of time in advanced mathematics and geometry courses. Experimental studies can be conducted to examine their effects on students' cognitive load comparatively. DMLOs can be offered to higher education students taking mathematics courses in different departments of universities. In addition to regular teaching, it may be useful to ensure the use of DMLOs as extracurricular materials through mobile devices. We suggest that material design courses should include topics on the development of such applications so that pre-service teachers can use these types of DMLOs in their future careers. In-service professional development training can be offered by the relevant units in universities for faculty members working in mathematics departments to design and use such applications in their courses.

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