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Effectiveness of Multimedia Instruction Based on Cognitive Theory on Academic Motivation and Mathematics Achievement for Students in Distance Education Centers

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ABSTRACT

Objective: The primary objective of the current investigation is to explore the effect of multimedia instruction based on cognitive theory on academic motivation and mathematics achievement for students in distance education centers.

Methods: The methodological approach employed in this inquiry is quasi-experimental, utilizing a pre-test-post-test design in conjunction with a control group. The statistical population encompasses all first-year secondary school students enrolled in distance education centers situated in the 2nd Education District of Arak city. A cluster random sampling technique was implemented, whereby two distance education centers were randomly selected from the specified population, and 40 participants from these centers were randomly allocated into experimental and control groups following a matching process. The control group was subjected to traditional educational practices prevalent in distance education centers, whereas the experimental group was instructed in the first and second chapters of mathematics for first-year secondary students through the utilization of multimedia developed by the researcher. Data were acquired via a researcher-developed mathematics academic achievement scale and the educational motivation scale, both of which demonstrated confirmed validity and reliability.

Results: The outcomes derived from the multivariate analysis of covariance indicate a statistically significant advantage of the experimental group concerning the variables of mathematics achievement and academic motivation among students.

Conclusions: The results of our investigation substantiate the significance of multimedia instruction in enhancing academic performance and educational motivation, thereby indicating its efficacy as a pedagogical strategy for educators.

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Introduction

Education and learning have always been one of the fundamental concerns of mankind. However, in the contemporary world, and especially in the 21st century, this process is recognized as a key element for achieving success at the individual and social levels. In this era, when we are witnessing the transition from an industrial society to an information society, economic growth is no longer the main goal, but the development and strengthening of human resources has become more important. These human resources are recognized as a valuable and strategic asset in today's societies. In other words, empowering individuals and improving their level of awareness and skills plays an effective role in the progress of societies and can be considered as a determining factor in the path of sustainable growth and development (Adipat et al., 2021). Improving the learning process and developing education has long been the focus of researchers. Given the advances in educational technology, continuous efforts are being made to innovate teaching methods and improve the quality of education. The learning and education process, in terms of its specific characteristics, includes various dimensions and elements, each of which interacts with each other. These interactions are formed in such a way that each element influences and is influenced by the other. In this way, a deeper understanding of how these components function and their mutual effects can help improve teaching methods and the quality of learning. Research in this field can lead to the identification of more effective solutions and optimization of the learning process (Rezazadeh Shermeh & Hashemi, 2020). Multimedia has significantly transformed the nature of reading. Instead of limiting the reading experience to printed and linear texts, these technologies have made the learning process dynamic and mobile by providing new methods. In these multimedia environments, words not only act as a tool for conveying meaning, but also serve as axes for creating further connections. Readers can expand texts and achieve a deeper understanding of topics by using these tools. This expansion of information is possible not only through the addition of text, but also by utilizing sound, images, music, and video. In this way, the reading experience becomes a comprehensive and multidimensional activity that greatly enhances interactivity and learning, and allows individuals to actively participate in the educational process (Farahani & Khoda Bande Loo, 2016). Multimedia is a combination of two or more forms of media that presents an educational program and an educational multimedia message, that is, communication using words and images that leads to learning (Mayer, 2005). If a multimedia is

produced without paying attention to the specific principles of educational multimedia design and without observing the global standards specified for an educational multimedia, and the multimedia merely includes a series of text, graphics, animation, video, and audio, it will actually be nothing more than a television advertisement (Clark & Mayer, 2023). In the last fifty years, there have been educational reform movements in the world, especially in the United States, regarding mathematics education (Boyle, 2013).

Today, with the increasing challenges and educational problems such as the large number of students, the shortage of teachers, and the increase in education costs, special attention has been paid to the use of modern educational technologies, especially multimedia. Due to their multisensory nature, these types of media have the ability to adapt to different learning styles, and for this reason, their production is expanding. However, one point that should be noted is that media, in addition to their benefits, can incur high costs and lack the necessary efficiency if design standards and principles are not observed. Unfortunately, many multimedia software manufacturers mainly focus on its commercial aspects and the quality of their products is not desirable. In order to design and produce an effective and efficient multimedia educational software, in addition to originality and innovation, it is necessary to observe the standards and features that experts in this field have identified and developed. Therefore, it is essential that manufacturers pay attention to these principles so that they can help improve the quality of teaching and learning. News processing theory is one of the key topics in the field of cognitive learning. This theory emphasizes the importance of human attention to the surrounding environment, encoding information, and its connection with previous knowledge. In this process, information is transferred to memory and can be retrieved when needed. One of the fundamental points in educational psychology based on news processing theory is the theory of cognitive load. This theory states that the capacity to process information in the human mind is limited and we are only able to process a certain number of information units at any given time. Cognitive load refers to the amount of pressure placed on working memory during information processing, which is necessary to encode information in long-term memory (Sweller, 2011). This mental effort and the amount of pressure imposed on working memory are known as cognitive load. In other words, understanding this theory can help to better understand how humans learn and process information

and provide solutions to optimize the learning process (Rahbar & Ahmadi, 2023). Studies in the field of cognition show that human learning is influenced by a basic cognitive structure that includes long-term memory and short-term memory. Short-term memory, with its limited capacity, is responsible for temporarily storing information, while working memory, as the main cognitive processor, plays a fundamental role in creating and combining mental representations and retaining relevant information in a short period of time. On the other hand, long-term memory, as the repository of our knowledge, stores information in the form of organized patterns. These memory structures allow us to process and understand information effectively and achieve deeper and more lasting learning (Hoseinzadeh et al., 2019). In recent years, researchers and theorists in the field of cognitive load theory have paid special attention to examining the cognitive characteristics of learners and how they process information. This attention has contributed to effective and efficient educational design using multimedia materials. In fact, a better understanding of how individuals learn and process information can lead to the development of more optimal and appropriate educational methods. For this reason, the importance of recognizing learners' cognitive capacities in the process of designing and producing multimedia educational content is clearly evident. This approach not only helps to improve learning, but can also make the learning experience richer and more engaging for students (Kalyuga, 2011).

Several factors affect individuals' educational performance, which ultimately determine the quality of the educational system. Among these factors, motivation is recognized as one of the most key elements. This concept means that motivation can play a fundamental role in students' academic success. In other words, motivation and enthusiasm for learning not only affect an individual's effort and pursuit in the educational process, but can also affect the way they interact with the educational environment and their academic results. Therefore, paying attention to student motivation and trying to increase it can help improve the quality of education and learning (Rostaminejad et al., 2019).

Learning motivation is known as an internal force in an individual that is characterized by the emergence of different emotions, reactions, and behaviors towards specific topics. This concept indicates an individual's desire to acquire new knowledge and skills and can act as a stimulus for educational and academic activities. Learning motivation is not only influenced by internal factors such as interest and curiosity, but also environmental and social conditions play an important role

in its formation and strengthening. In other words, this motivation can be influenced by past experiences, expectations of the future, and even cultural influences. Therefore, a deeper understanding of learning motivation can help improve educational processes and increase learning efficiency (Kurniawan et al., 2022). Motivation, as a basic prerequisite for attracting attention to learning materials, is of great importance in the learning process. One factor that can help improve this process is the use of educational media. According to Wahyuningtyas and Kristin (2021), these media can increase students' motivation in the learning process and provide an attractive and entertaining environment for learning. Therefore, the use of technology and various educational tools can have a significant impact on stimulating students' interest and excitement, thus making the learning process richer and more effective. Educational media play an important role in increasing students' motivation in the learning process and can provide an attractive and lively environment for education. Teacher creativity in designing and delivering education is considered a key factor in improving the quality of teaching-learning. When students' motivation to learn increases, this has a significant positive impact on their learning outcomes. Therefore, the effective use of educational media and teacher innovations can help create a dynamic and motivating environment in which students learn more easily and eagerly. This will ultimately lead to improving their knowledge and skills (Saputra et al., 2018). Success in achieving learning goals depends on the level of interest and enthusiasm of students to participate in educational activities. For this reason, paying attention to students' motivation in the learning process is vital. This requires teachers to work with sufficient skills and knowledge in designing and implementing the learning process. In other words, teachers must have the ability to create an environment in which students are actively and enthusiastically engaged in learning. Therefore, the appropriate design of learning activities can help to enhance students' motivation and enthusiasm, and as a result, facilitate the achievement of better educational outcomes. In this regard, teachers' deep understanding of students' needs and interests can play an important role in motivating and increasing their participation.

One of the most important educational competencies that teachers must master is the ability to use technology in the learning process. When selecting and using educational materials, it is essential that the instructor pays special attention to adapting technology to the current conditions and needs.

This ability not only helps to increase the quality of education, but also motivates and engages students more in learning. Therefore, teachers should have a deep understanding of modern tools and educational technologies and use them in a way that facilitates learning and enhances the educational process (Wibowo et al., 2022). Multimedia, as one of the modern media tools, offers extensive capabilities in the field of teaching and learning in schools. The use of multimedia technologies in the educational process not only increases the attractiveness of the content, but also helps to strengthen the understanding and recall of the material. By creating an interactive and dynamic environment, these tools encourage students to actively participate in the learning process, and thus, their cognitive abilities and social skills are also strengthened. As a result, the use of multimedia in schools can be considered an effective solution in improving the quality of teaching and learning.

In 2001, Mayer (2014) presented principles for effective multimedia design in education, which include seven main principles. These principles are designed to enhance learning and optimize the educational process. Each of these seven principles emphasizes the interaction and coordination between text, image, and sound in some way so that learners can process and understand information in the best possible way. The aim of these principles is to reduce cognitive load and increase the attractiveness of educational materials. Ultimately, this approach helps learners understand concepts better and remember information more effectively, which are as follows: 1- Multimedia principle: It reflects the fact that more effective and deeper learning occurs when learners benefit from the combination of words and images, rather than relying solely on written texts. This principle is based on scientific research in the field of learning and education and shows that the simultaneous use of visual and textual elements can facilitate the learning process. Combining these two types of content helps learners to better understand information and retain it in their memory. 2- The principle of spatial proximity: It refers to the fact that effective learning occurs when related information, such as images and texts, are placed near each other. In fact, placing words and images next to each other helps the connection between them to be better understood and the learner can process the information easily. 3- The principle of temporal proximity: It is based on the fact that when related words and images are presented simultaneously and simultaneously, learners' learning improves. In fact, this principle shows that combining visual and textual information in such a way that learners can pay attention to them concurrently can

facilitate the learning process. 4- The Principle of Coherence: This refers to the concept that effective learning occurs when course materials are presented in a coherent and related manner. In fact, the use of irrelevant and unrelated information can disrupt the learning process and prevent learners from understanding the material in depth. In other words, to enhance learning, it is essential that educational materials are designed in a way that is consistent with each other and prevents information from being scattered and overlapping. This principle emphasizes that the correct and logical organization of course content will facilitate learning and understanding of concepts. In this regard, paying attention to the continuity of subject matter and their relationship to each other can help increase attention and motivation in learners, ultimately leading to more lasting and effective learning. 5- The Principle of Sensory Channels: This points out that learners' learning is significantly affected by the way information is presented. Research shows that learners benefit more from animation combined with oral expression when presenting educational content than when information is presented in the form of printed text on the screen.

6 -The Principle of Redundancy or Surplus: This points out that learners usually experience better learning through a combination of animation, oral expression, and printed text. Research shows that presenting information in multimedia can increase the effectiveness of learning. In this regard, the simultaneous use of animation and oral expression as two rich sources of information can help to understand the material more deeply.

7 -The principle of individual differences: The effect of multimedia educational design on learners with less knowledge is greater and more effective than on those with more knowledge, and also on learners with high spatial understanding compared to those with low spatial understanding. The results of the study by Hoseinzadeh et al. (2019) entitled The Effect of Multimedia Educational Design Based on the Principles of Cognitive Load Theory on Learning, Retention, and Motivation for Academic Achievement in Mathematics showed that multimedia educational design based on the principles of cognitive load theory shows, with 95% confidence, that it has a positive effect on students' learning, retention, and motivation for academic achievement in mathematics. This study clearly states that designing multimedia educational content based on this theory, especially for female students in the fifth grade of elementary school, has yielded significant results in the fields of learning and academic motivation. Thus, it can be understood the importance of paying attention

to the principles of cognitive load theory in designing educational content, because this approach can help improve the learning process and strengthen students' academic motivation.

Rahbar and Ahmadi (2023) conducted a study entitled "Quality of Virtual Physics Education by Designing Educational Content Based on the Principles of Cognitive Load Theory". They ultimately concluded that observing the principles of cognitive load theory in the production and design of educational content has a significant impact on academic achievement, increasing retention, and reducing perceived cognitive load by students.

Farahani and Khoda Bande Loo (2016) conducted a study titled “Investigating the Effect of Standardized Educational Multimedia in the Framework of Cognitive Multimedia Theory on the Level of Learning and Attitudes to Mathematics Lessons of Distance Education Center Students”. The results showed that the use of multimedia content designed based on the cognitive theory of multimedia is much more effective than traditional teaching methods in these centers. This study emphasizes the importance of designing educational content in accordance with cognitive principles and states that such an approach can help improve students’ learning and positive attitudes toward mathematics lessons.

In a study by Rezazadeh Shermeh and Hashemi (2020), titled “Comparing the Effects of Educational Methods Based on Cognitive Load Theory, Multimedia, and Lectures on Students’ Learning in Science,” the results showed that students who received training based on cognitive load theory performed significantly better in terms of learning and motivation than their peers who received multimedia and lecture-based training in science. These findings indicate that educational methods based on cognitive load theory can have more positive effects on the learning process and increase students’ motivation.

The findings of Zarabian (2019) study, titled "Investigating the Effect of Electronic Content Based on Multimedia Design Principles on Learning Mathematics and Science Lessons of Sixth Grade Elementary School Students," showed that the use of electronic content designed based on multimedia design principles and aesthetic principles had a positive effect on the learning rate of students in the experimental group in all concepts in science and mathematics lessons compared to themselves and also compared to the control group. Badeleh and Izadikhah (2019), in their study titled "Comparing the Learning and Retention Rate of Female Second Grade Elementary School Students in Webquest, Mobile, and Flipped Learning Methods of Experimental Science Lessons,"

concluded that there are significant differences between learning and retention scores in Webquest, Mobile, and Flipped Learning methods. Specifically, evaluations show that mobile learning has a greater impact on students' learning process, while the Webquest method is more effective in information retention. These findings indicate that each of these methods, according to its specific characteristics, has different results in the field of learning and retention, and it seems that choosing an appropriate method can help improve students' educational performance. Therefore, analyzing these methods and their effects on learning and retention can lead to the development of more effective educational strategies.

In another study conducted by Rostaminejad et al. (2019) entitled "Investigating the Effect of Humor-Based Electronic Content-Based Teaching on Math Motivation and Anxiety in Fifth Grade Elementary School Students." The findings of this study showed that the use of humor-based electronic content did not have positive results in influencing students' motivation and math anxiety in the fifth grade elementary school. In other words, this type of content has not been able to improve positive emotions or reduce anxiety in the field of math learning among this age group. This issue may require further analysis to determine the reasons for the lack of impact of humor content on the learning process and motivation in students at this age.

Zakaria et al. (2025) In a study titled "The Effect of Mobile Learning and Problem-Based Learning on Students' Motivation and Academic Performance," the results showed an increase in students' motivation and problem-solving skills compared to traditional methods in math lessons.

Balasabas (2024) in his study titled The Impact of Modular Distance Learning on Mathematics Performance of Junior High School Students after the Pandemic: A Teacher's Perspective concluded that the mathematics learning of tenth grade students was significantly affected by the modular distance learning method during the pandemic.

Abd Al-Aziz et al. (2024) conducted a study titled The Impact of Wordwall on Academic Achievement and Mathematics Learning Motivation among Sixth Grade Students in the Nablus Region, and ultimately concluded that the use of the Wordwall platform has a positive effect on developing academic achievement and increasing the motivation of sixth grade students towards mathematics learning.

Research findings Johnson et al. (2024) entitled "Comparing the Academic Performance of Students Trained with Educational Technology with Multimedia Instruction in Hesitation-Based Classroom and Online Educational Environments" showed that multimedia instruction designed with Hesitation-Based Classroom had a significantly positive impact on the progress of undergraduate students in the field of educational technology. This effect was especially evident in face-to-face classes as well as in online environments. The results of the research conducted indicate that the use of this type of instruction can help improve students' learning and understanding of concepts. In addition, this educational method allows students to encounter a greater variety of educational content and more active interactions, which in turn increases their motivation and interest in learning. Finally, these findings indicate that integrating multimedia instruction with modern teaching methods can be used as an effective tool in improving the quality of learning.

Prasetyo et al. (2024) in their study titled Development and Construction of Interactive Multimedia Media for Eleventh Grade Mathematics Education concluded that interactive multimedia-based learning can increase motivation, learning independence, and is a solution for making mathematics learning attractive and understandable.

In another study conducted by Yaftian and Barghamadi (2022) titled The Effect of Teaching Using Multimedia on Math Anxiety and Motivation, the results showed that there was a significant difference between the two groups in each of the dependent variables and that the use of multimedia systems affected students' motivation and anxiety in mathematics.

The findings of the study by Rajendran et al. (2025) titled Game-Based Learning and its Effect on Student Motivation and Academic Performance showed that customized game-based instruction was effective in increasing student motivation, engagement, and positive attitude.

Another study by Far'i et al. (2023) titled The Effect of Multimedia-Aided Problem-Based Learning Model on Student Motivation for Learning. The findings of this study showed that students who were taught using the multimedia-aided problem-based learning model showed an increase in their learning motivation in mathematics.

Serly et al. (2023) conducted a study titled The Effectiveness of Multimedia PowerPoint in Increasing Motivation and Improving Cognitive Science Learning Performance of Elementary School Students. The results of this study showed that the average cognitive science scores of

elementary school students trained with PowerPoint and multimedia were higher than those of conventional methods.

Saupi and Said (2022) in a study titled The Use of Interactive Multimedia in Distance Mathematics Teaching and Learning, it was found that students showed positive attitudes and high motivation towards the use of this type of media in the online mathematics learning process. This study shows the positive effects of interactive multimedia on students' learning experience and indicates that such tools can help improve the quality of education and increase student participation in mathematics learning. The conclusion of this research clearly demonstrates the importance of paying attention to the design and use of multimedia tools in the teaching and learning process, and allows us to use these tools better in online education.

Based on previous materials, various studies have shown that the use of multimedia in the educational process has a significant impact on learners' learning. However, few studies have addressed the extent of the impact of a multimedia produced within the framework of cognitive theory on the level of learning and academic motivation of students. Therefore, researchers are trying to give more importance to this issue and thereby focus the attention of future researchers on the production of multimedia within the framework of cognitive theory. For this purpose and to achieve the desired goal, two partial goals have been considered for the present study as follows: 1- Comparing the level of learning in the mathematics subject of the first grade of secondary school among students using research-made educational multimedia and students using conventional methods in distance education centers. 2- Comparing the level of motivation for academic achievement among students using research-made educational multimedia and students using conventional methods in distance education centers.

Material and Methods

This research is applied in terms of purpose and quasi-experimental in terms of research method with a pre-test-post-test design and a control group. The target population in this study is all male distance education centers in the secondary school level of Arak city, which are located in the 2nd education district of Arak city. To minimize the effect of unwanted variables, a cluster random sampling method was used. Accordingly, 2 centers and 2 classes were randomly selected from the

distance education centers. The sample size reached 24 people after matching. These people were randomly placed in two groups of 12 people. One group was randomly selected as the experimental group (using researcher-made multimedia) and the other was randomly selected as the control group (using current methods in distance education centers). All participants in this study gave their written consent after being informed of the research objectives and methods.

Instruments

Teacher-made math test: Learning in this study was assessed by the scores of the teacher-made math test, according to the chapter of numbers and sets of the seventh grade math book. Out of 24 questions of this test, 14 questions were selected, including 7 descriptive answer questions, 4 multichoice questions, and 3 true-false questions. The content validity of the test was confirmed by the opinions of math teachers. In addition to the teachers' approval, the Kuder-Richardson method was used to measure the reliability of the questions, which yielded a reliability of 0.85.

Educational motivation scale: In order to measure students' academic motivation, the educational motivation scale was used. The main form of the questionnaire consists of 100 questions that measure two of the three dimensions of the Maher model, namely "personal incentives" and "self-esteem". The short form of this questionnaire was developed by Bahrani (2009) in Shiraz. This questionnaire has 49 items, which are arranged on a Likert scale from strongly disagree (1) to strongly agree (4), and has 11 factors of academic motivation. Of these 49 items, 5 items measure goal orientation, 4 items measure competitiveness, 3 items measure work and homework orientation, 4 items measure progress orientation, 5 items measure social dependence, 4 items measure social cooperation, 4 items measure fame seeking, 5 items measure material rewards, 4 items measure power seeking, 6 items measure self-esteem, and 5 items measure self-reliance. Scoring is done in reverse in some questions. The reliability coefficients of the 11 scales were also relatively high and the range of these coefficients varied from 0.70 (related to the scale of progress orientation) to 0.90 (related to the scale of extrinsic motivation). The median of the coefficients was also obtained as 0.77. Also, the internal consistency of the questionnaire used for the entire questionnaire was obtained as 0.77 and for different scales from a minimum of 0.27 (scale of progress orientation) to a maximum of 0.77 (scale of extrinsic motivation) with a median of 0.50.

Educational multimedia produced: The multimedia resource produced is the topics of numbers, exponents, and mathematical sets for the seventh grade of secondary school. Storyline software

was used in the creation of this multimedia, and other software such as Macromedia Flash, Photoshop, and Screen Recorder software were also used. The media used in this multimedia are text, film, animation, and audio (speech, music, and sound effects).

To produce this multimedia, the following characteristics were considered and emphasized from a technical perspective: General specifications of the software (installation, manual, and technical) include: 1) Statement of the characteristics of the creator/creators, product title, school name, and the possibility of contacting the producer at the beginning or in the About Us section. 2) Has the audience of the software, resources used, hardware, and software required to run the produced software been specified? 3) In designing the courseware, an attempt has been made to ensure that the audience with minimal knowledge and ability in the field of working with computers can use the software (automatic execution and installation of fonts or required software, attention to installation time); 4) The installation guide and the guide to using different parts of the software have been designed to make better use of the software's features. 5) Are there any technical problems in using different parts of the software? (Linking pages, going to links, playing videos and audio). The user interface specifications include: 1) Is the type, size, and color of the font used in different parts of the courseware appropriate? 2) The quality of still and moving images (brightness, clarity, size, color, and file size) and sounds related to music, speech (text and video) and sound effects (loudness, strength, clarity, and file size) is acceptable. 3) Attention has been paid to the simple and practical arrangement of visual elements (buttons, text, images) and audio on the pages. 4) The software has a correct map (main pages, entrance, title, list, lessons, sub-pages, help, about us, and address, the location of the audience on the lesson pages, and the correct use of icons, signs, and symbols on each page.

It is possible to display and control the sound (music, speaker's voice) and moving image used in the software. (Disconnect and reconnect, forward and backward, display the total and elapsed time of sound and image, and the number of pages in the entire lesson and the current page).

The test and evaluation specifications are: 1) There is a question bank and the possibility of reducing or adding questions to the question bank. Are the questions randomly selected and displayed?

It should be noted that this multimedia has been produced in the framework of the cognitive theory of multimedia, in accordance with the five principles of cognitive multimedia design and using the seventeen standards for the production and design of educational multimedia. Also, in the content dimension, the following characteristics have been considered in the production of multimedia:

The characteristics of the scientific accuracy of the content are: 1) The written content has scientific accuracy. 2) The written content (texts) has observed the writing ritual (literature and word typing). 3) Images (still and moving), graphs and charts have been selected in accordance with the content and audience (age and academic level.

The characteristics of the content coverage are: 1) The volume of educational content presented can cover the educational objectives related to each selected topic or subject. 2) The time allocated for teaching the content of each section is appropriate.

Supplementary educational content has been used in addition to the textbook content for better understanding and deepening of the material.

Design specifications include: 1) The interaction used in the teaching-learning process (problem-solving-persuasion-thinking-discovery and exploration and the audience's participation in the education process) is appropriate. 2) The graphic design used serves the content, audience, interaction and replaces text and writing.

To what extent do learning consolidation activities (examples and solved exercises) during education help to better understand the content.

Evaluation specifications include: 1) The necessary feedback on the evaluation conducted to fix problems has been given to the audience. 2) The number, variety and accuracy of evaluation questions and the level of difficulty are appropriate.

Data analysis method: Descriptive statistics indicators (frequency, mean, standard deviation) were used to analyze the research data, and multivariate analysis of covariance was used to inferentially test the hypotheses.

Results

Mean and standard deviation of academic motivation and mathematics learning scores in the experimental and control groups at the pre-test and post-test provided in table 1.

Table 1. Mean and standard deviation of academic motivation and mathematics learning scores in the experimental and control groups at the pre-test, post-test

Variable		Experimental		Control	
		Mean	SD	Mean	SD
Academic motivation	Pretest	75.08	8.60	74	7.7
	Posttest	87366	8.96	73.78	7.91
Mathematics achievement	Pretest	12.33	1.38	12.16	2.16
	Posttest	17.83	1.33	12.25	1.48

To examine the differences between the two groups in terms of academic motivation and mathematics learning, univariate and multivariate analysis of covariance were used. In this way, the pre-test scores of the subjects in the experimental and control groups were controlled and the analysis was performed on the post-test scores of the groups. Before stating the results of the analysis of covariance, it is necessary to state the assumptions related to this analysis method. Table 2 shows the results of the Levene test to examine the homogeneity of variances of the research variables in the experimental and control groups.

Table 2. Results of the Levine test to examine the homogeneity of variances of the research variables in the experimental and control groups

Variable	DF1	DF2	F	P
Academic motivation	1	22	0.14	0.70
Mathematics achievement	1	22	0.30	0.84

The results of Table 2 show that there is no significant difference between the experimental and control groups in terms of the variances of the research variables. Therefore, the assumption of equal variances was confirmed.

Table 3 shows the results of the test of homogeneity of regression slopes (another assumption of the analysis of covariance) in the experimental group and the control group.

Table 3. Results of homogeneity of regression slopes between covariate variables (pre-test) and dependent variables (post-test) at the factor levels (experimental and control groups)

Pretest	SS	DF	MS	F	P
Academic motivation	0.70	2	0.35	0.05	0.95
Mathematics achievement	0.44	2	0.22	0.22	0.80

As can be seen in Table 3, the interaction of covariate variables (pre-tests) and dependent variables (post-tests) at the factor levels (experimental and control groups) is not significant. Therefore, the assumption of homogeneity of regressions has been met. To examine the effect of the group on academic motivation and learning mathematics, a multivariate analysis of covariance test was used (Table 4).

Table 4. Results of multivariate analysis of covariance on the means of dependent variables (academic motivation, learning mathematics) in the experimental and control groups

Test	Value	F	Hypothesis DF	Error DF	Effect size	Power	P
Pillai's trace	0.86	20.28	4	15	0.86	1	0.001
Wilk's Lambda	0.14	20.28	4	15	0.86	1	0.001
Hotelling's Trace	6.36	20.28	4	15	0.86	1	0.001
Roy's largest root	6.36	20.28	4	15	0.86	1	0.001

The results of Table 5 show that there is a significant difference between the post-test scores of the experimental and control groups in terms of at least one of the dependent variables. To find out this difference, four analyses of covariance were performed in the MANCVA, the results of which are included in Table 5.

Table 5. Results of ANCOVA analysis embedded in MANCOVA on the means of dependent variables in the experimental group and the control group in the post-test stage

Variable	SS	DF	MS	F	Effect size	Power	P
Academic motivation	29.75	1	29.75	21.52	0.24	0.62	0.02
Mathematics achievement	58.01	1	58.01	70.43	0.79	1	0.001

The results of Table 5 show that the difference between the experimental group and the control group in the post-test stage is significant in terms of the variables of academic motivation and learning mathematics at the desired level ($p<0.05$).

Discussion

The results of the present study showed that a multimedia that meets appropriate design criteria can have a greater impact on students' learning and academic motivation compared to other educational methods. The results of this study are consistent with the results of other studies conducted on the effects of educational multimedia on desired learning, including the research of Hoseinzadeh et al. (2019), Rahbar and Ahmadi (2023), Farahani and Khoda Bande Loo (2016), Rezazadeh Shermeh and Hashemi (2020), Zarabian (2019), Badeleh and Izadikhah (2019), Zakaria

et al. (2025), Balasabas (2024), Abd Al-Aziz et al. (2024), Johnson et al. (2024), Prasetyo et al. (2024), Yaftian and Barghamadi (2022), Rajendran et al. (2025), Far'i et al. (2023), Serly et al. (2023), Saupi and Said (2022) are consistent.

Student activity and participation in the learning process is considered one of the key approaches to achieving sustainable and effective learning. In this regard, the use of multimedia tools has been given special attention. These tools, by simultaneously integrating a variety of senses, allow students to receive information in a more comprehensive way. As a result, this process not only helps to better understand concepts, but also increases students' motivation to learn more. Given that learning through interaction and active activity provides a suitable context for facilitating the understanding and retention of information, it can be expected that the use of multimedia as an effective educational tool will play a significant role in improving the quality of learning. Multimedia learning points out an interesting point that effective comprehension of the material is achieved when learners can establish meaningful connections between different sensory information. This connection allows them to relate multifaceted symbols to each other. Establishing this type of connection in the learning process helps to strengthen mental abilities and, consequently, learning will reach a deeper and more sustainable level. In other words, the ability to combine information from different sources and create a coherent conceptual framework will not only help facilitate understanding of the material but will also lead to more effective and lasting learning. In fact, this process allows learners to absorb knowledge in a deeper and more sustainable way by using their cognitive abilities. As is evident from the research background, although many studies emphasize the positive impact of multimedia in the educational process, it should be noted that the success of these tools depends on the quality and design of them. In distance learning centers, compact discs known as multimedia are often presented in the form of educational films and are structurally different from real multimedia. In this type of education, students learn more independently and responsibly and have a lot of control over the time and place of their learning. This allows them to manage the learning process based on their time and abilities and strengthen their sense of responsibility. Therefore, these types of educational environments are designed in such a way that students learn more self-directedly and for this reason, the audience of these virtual educations achieves an internal source of control.

Considering the principles of cognitive multimedia theory and the findings of this study, it can be concluded that the active activity of the learner, increasing the audience's motivation, and creating a meaningful and deep connection in a multimedia content that is designed based on the principles and criteria of cognitive theory are far more effective and efficient than multimedia content that, although has high-quality graphic effects and interactivity, lacks these principles. As mentioned in the research literature, although many studies indicate the success of using multimedia in the educational process, it should be noted that the extent of this success depends on the way multimedia content is designed and produced. In other words, simply having visual and interactive features is not enough for success in education, and special attention should be paid to the principles of learning and educational design. Such research should be conducted in different subject areas, at different levels of education, and with respect to both genders, including men and women, in the field of adult education. Also, combining multimedia with modern teaching methods and examining their effects in distance learning centers also needs to be studied. The results obtained from this research can be of great help to administrators, teachers, educational policy makers, students, and producers of multimedia educational materials. This research not only helps to improve educational methods, but can also lead to improving the quality of learning and creating educational environments that are appropriate to the different needs of society.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by ethics committee of Farhangian University.

Author contributions

All authors contributed to the study conception and design, material preparation, data collection and analysis. The author contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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