Mathematics Education Journal
ISSN: 2549-1040 (e) | 1978-0044 (p)
https://doi.org/10.22342/mej.v19i3.pp465-488

Reducing Cognitive Load using Social Persuasion Prompts in Mathematics Multimedia Learning

Yanuar Hery Murtianto[1], Endah Retnowati[1,*], Jose Hanham[2]

[1]Mathematics Education Department, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia,
[2]Postgraduate Studies, School of Education, Western Sydney University, Sydney, Australia
[*]Email: e.retno@uny.ac.id

Abstract

Although self-efficacy is widely acknowledged as a key to academic success in mathematics, limited research has examined how social persuasion strategies can be systematically integrated into multimedia learning to enhance self-efficacy and manage cognitive load. This study addresses the gap by examining the effects of integrated social persuasion prompts within mathematics instruction, focusing on cognitive load, self-efficacy, and problem-solving achievement. The first experiment compared worked example-based instruction with and without social persuasion, involving 66 undergraduate students enrolled in a multivariable calculus course for the first time. Instructional materials on parametric equations were delivered in a printed booklet and designed in alignment with Cognitive Load Theory. Social persuasion prompts were written on top of each worked example and problem-solving. The findings revealed that there was no significant different impact of written social persuasion, however the social persuasion significantly reduce cognitive load but increase self-efficacy. The second experiment recruited another 56 undergraduate students enrolled in the same multivariable calculus course studied the same worked examples in the format of multimedia. The results demonstrated that there was a strong impact of audio social persuasion on worked examples with regards to achievement, cognitive load, and self-efficacy level. This study provides profound evidence for integrating social persuasion in worked examples as it could enhance achievement, lower cognitive load, and improve self-efficacy. Further research on audio-based persuasion in multimedia format is discussed.

Keywords: Cognitive Load Theory, Mathematics, Multimedia Learning, Social Persuasion, Self-efficacy, Achievement

How to Cite: Murtianto, Y. H., Retnowati, E., & Hanham, J. (2025). Reducing cognitive load using social persuasion prompts in mathematics multimedia learning. *Mathematics Education Journal, 19*(3), 465-488. https://doi.org/10.22342/mej.v19i3.pp465-488

INTRODUCTION

The development of the Cognitive Load Theory (CLT) has a significant impact on one's understanding of the nature of processing that occurs in individuals during the learning process. The cognitive load theory, which was developed by Sweller (1988; 2023), proposes that the human cognitive system has a limited capacity for comprehending new information. This limitation necessitates strategies that prioritize efficient information processing. It is crucial to control the cognitive load generated by instructional resources accurately to meet the goal of facilitating efficient learning. Learning outcomes can be significantly enhanced when instructional materials are designed to minimize unnecessary cognitive load, optimize intrinsic load, and promote relevant processing, thereby improving learners' ability to develop meaningful schemas (Hsu, 2020). Moreover, an increased amount of extraneous cognitive load could prevent learning by overwhelming learners with abundant information or limiting their ability to acquire new knowledge quickly (Tugtekin & Odabasi, 2022). Therefore, reducing unnecessary cognitive load is critical in designing effective learning experiences. The effectiveness of learning is influenced by the cognitive load.

Received December 22, 2024; Revised May 16, 2025; Accepted June 10, 2025

Three categories can be used to classify cognitive load: intrinsic load, which refers to the complexity of the learning task itself; extraneous load, which refers to how information is delivered; and germane load (Chen et al., 2023; 2024; Lawson & Mayer, 2024). Each type plays a distinct role in the learning process. In contrast to the intrinsic load, which is associated with the complexity of the material, the extraneous load is concerned with the presenting format, and the germane load is related to the amount of work that is put into digesting information in a meaningful way.

In recent years, the teaching approach known as multimedia learning, which makes use of a variety of different media to enhance learning performance, has gained a lot of popularity. Only by making a modest adjustment to how information is presented may ineffective multimedia design result in an increase in the amount of superfluous cognitive load (Kaewsa-Ard, 2021; Mayer, 2019; 2014). For instance, a dual-coding method is utilized by including both visual and audio components in the overall design. According to Moreno and Mayer (2000), this not only assist individuals in comprehending the information, but it also helps them recall it better than other methods of presentation.

One of the most effective instructional techniques derived from CLT is the use of worked examples for novices. A worked example is a step-by-step demonstration of how to solve a problem or complete a task, which serves to guide learners through the problem-solving process. By reducing the cognitive demands placed on learners, worked examples have been shown to enhance learning outcomes (Sweller, 1988; 2020; Sweller et al., 2019).

The rationale behind using worked examples is rooted in the concept of the cognitive load. When learners are confronted with a novel task, the intrinsic cognitive load (related to the inherent complexity of the task) can overwhelm working memory. By presenting worked examples, the extraneous cognitive load (which arises from unnecessary information or poorly structured learning materials) is minimized, allowing learners to focus their cognitive resources on understanding the essential content (Sweller, 1988; 2020). Over time, learners can gradually increase their problem-solving capabilities through progressive learning, such as moving from worked examples to independent problem-solving (van Merriënboer & Sweller, 2005). Novices benefit more from worked examples, while experts may perform better with less direct guidance and more opportunities for independent problem-solving (Kalyuga, 2007). This principle, known as the expertise reversal effect, underscores the importance of adapting instructional strategies to the learners' level of expertise.

Even though there are many benefits associated with learning through multimedia, individual differences in motivation and self-efficacy can have a significant impact on the outcomes of learning. An individual's level of self-efficacy can be defined as their belief in their abilities to carry out the actions required to achieve their goals (Bandura, 1997). According to research conducted by Schunk (1991), this supportive attitude has an impact on the students' ability to persevere in their pursuit of knowledge, their level of desire, and, ultimately, their academic performance. It is possible to mitigate the adverse consequences of cognitive loads by maintaining a high level of self-efficacy. On the other hands, learners who have sufficient self-efficacy can approach obstacles with confidence and the ability to resist the need to retreat (Zimmerman, 2000).

It might be possible to accomplish an increase in learning outcomes by including self-efficacy strategies in multimedia learning settings. These strategies not only reduce the amount of unnecessary cognitive load, but they also boost the learners' belief in their capabilities. Among these techniques might be the self-setting of objectives, the monitoring of oneself, and the provision of feedback to oneself; these are all measures that are aimed at boosting self-efficacy motivation (Bandura, 1997; Pintrich, 2003).

However, the effects of combination interventions with multimedia learning and integrated self-efficacy on cognitive load or learning performance are not well supported by the available research. To address this gap, the purpose of the present study is to explore the impacts that self-efficacy interventions paired with multimedia learning have on cognitive loads in comparison to other instructional approaches. The study makes a contribution to the expanding body of literature in this field by investigating how various learning environments influence the cognitive load and academic performance of students.

Self-efficacy is the belief in one's abilities to carry out activities and achieve goals, in compliance with Bandura's (1977) definition. Students' motivation, determination, and resilience, which impact their academic achievements, are positively correlated with their level of self-efficacy. The integration of self-efficacy strategy into multimedia learning can reduce unnecessary cognitive load and create a better setting for learning. More specifically, the investigation will concentrate on the combination of self-efficacy interventions and multimedia learning that affects both cognitive loads and students' accomplishment. In comparison to traditional methods of education, it is expected that the use of multimedia learning in conjunction with social persuasion prompt strategies will result in a reduction in the number of cognitive loads and an increase in the level of achievement among students.

This study proposes that the integration of social persuasion prompts within multimedia learning environments can significantly influence learners' cognitive and motivational processes. Specifically, it is hypothesized that embedding persuasive verbal cues—such as encouragement and positive feedback—into multimedia instructional materials can help manage cognitive demands by directing attention, reducing extraneous load, and fostering a more focused learning experience. Therefore, the first hypothesis posits that social persuasion prompts in multimedia learning significantly reduce cognitive load by supporting learners' mental processing and promoting more efficient use of cognitive resources.

In addition to cognitive benefits, this study also considers the role of social persuasion in shaping learners' beliefs about their capabilities. Grounded in the principle that verbal encouragement can strengthen individuals' confidence to succeed in challenging tasks; the second hypothesis proposes that social persuasion prompts in multimedia learning environments have a significant impact on students' self-efficacy. By delivering affirming messages through audio narration, the instructional design aims to foster a positive academic mindset and increase students' belief in their ability to engage with and master complex mathematical content.

Lastly, given the motivational and affective benefits associated with social persuasion, the third hypothesis asserts that social persuasion prompts in multimedia learning—particularly those delivered through positive feedback—have a greater impact on student achievement. This hypothesis is grounded in the expectation that increased self-efficacy and reduced cognitive load will translate into improved academic performance, especially in tasks requiring conceptual transfer and application. Together, these hypotheses form the basis for examining how strategically designed multimedia instruction can support students' learning outcomes in mathematics.

Furthermore, multimedia learning based on cognitive load theory in this research can significantly contribute to achieving Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education). By optimizing cognitive load, multimedia tools can enhance learning outcomes, support inclusive education, and provide personalized learning experiences. Implementing these principles in educational design can help create effective and engaging learning environments that align with the goals of sustainable development. By considering these cognitive load principles and design strategies in this research, educators can create effective multimedia learning experiences that support the understanding and implementation of SDGs.

Finally, the urgency of this research lies in determining how to effectively present social persuasion prompts within multimedia instruction to reduce cognitive load and enhance self-efficacy and student achievement, particularly in college-level mathematics learning. This study addresses a gap in previous research, which has largely examined the independent roles of multimedia in instruction and strategies for increasing self-efficacy by managing cognitive load, but has not systematically integrated these elements. Moreover, this research responds to the limited empirical evidence regarding the impact of social persuasion prompts embedded in multimedia on learning outcomes in mathematics. By exploring the intersection of multimedia design, cognitive load reduction, and motivational enhancement, this study aims to provide a comprehensive understanding of how social persuasion can be strategically leveraged to improve students' learning experiences and academic success.

METHODS

A 2×2 factorial experimental design was employed, involving 122 pre-service mathematics teacher students from three universities in Central Java, aged 18 to 23, with approximately 75% female and 25% male participants. This design followed the procedure outlined by Morris (2010). All participants had completed foundational calculus coursework and were enrolled in a multivariable calculus course. They were randomly assigned to one of four experimental groups, defined by two factors: instructional mode (multimedia vs. non-multimedia) and the presence or absence of social persuasion prompts. The instructional intervention included worked examples on parametric equations, followed by problem-solving tasks and self-assessments of cognitive load and self-efficacy. Data were analyzed using Analyses of Variance (ANOVA) to examine the effects of instructional design on both learning outcomes and psychological responses. Detailed information regarding the participants, instructional materials, experimental procedures, instruments, and data analysis is provided in the subsequent sections.

Participants

This study included the participation of a total of 122 undergraduate pre-service mathematics teacher students who were enrolled in three different universities located in Central Java. The range of their ages was from 18 to 23 years old. All of the participants in the study had identical exposure to core educational theories and practices as a result of their pre-service teacher training, even though their academic backgrounds were quite different. In terms of gender, the group consisted of both male and female students, with an approximate distribution of 75% female and 25% male. The demographics of the participants included both genders. The participants were in their second to fourth year of their undergraduate programs when they were allowed to participate. Three universities that participated in this study have similar programs on mathematics education that include calculus as a compulsory course. Prospective mathematics teachers at the three universities all require students to take multivariable calculus, with the condition that students have taken calculus in semester 1 and differential calculus in semester 2.

The participants were randomly assigned by classroom to one of four experimental groups, with each group representing a different learning condition. These are Group 1: Multimedia learning with social persuasion prompts (MM + SP), (n = 30); Group 2: Multimedia learning without social persuasion prompts (MM – SP), (n = 31); Group 3: Non-multimedia learning with social persuasion prompts (Non-MM + SP), (n = 30); and Group 4: Non-multimedia learning without social persuasion prompts (Non-MM – SP)**,** (n = 31). The participant's eligibility was screened and confirmed by the lecturers. The students who participated in the study were all enrolled in the teacher education programs, which meant that they were future educators who had completed basic coursework and were currently participating in their undergraduate studies. The educational background of all of the participants consisted of having completed basic courses in calculus, which served as a common baseline for comprehending the theoretical material of the experiment. Therefore, it was possible to generalize the findings because of the different educational contexts that were present at each of the three universities. Additionally, the random assignment of participants to the groups ensured that the study design was robust and minimized any potential biases that could have been caused by prior knowledge or individual variations.

Materials

The learning management system (LMS) consisted of an initial apperception (10 minutes) with a learning scheme that included solving parametric equation problems, parametric problems with implicit functions, and parametric equations with explicit functions. After completing the apperception, the students then watched the multimedia in the form of an instructional video embedded in the LMS for approximately 20 minutes. After watching the multimedia, the participants completed a problem-solving test with transfer questions on the parametric equation material. The cognitive load theory and self-efficacy measures were conducted by completing a self-rating form after the participants had spent approximately 25 minutes solving the problem.

As part of the design, and as illustrated in Figure 1, the integration of multimedia elements, presented through social persuasion prompts, serves to motivate the audience by showcasing the application of parametric equations in the domains of graphic design and computer animation. This motivation employs the voice of the pedagogical agent in the multimedia before the initiation of the instructional material. The presentation of multimedia devoid of social persuasion entails the presentation of material directly to the concept to be learned, obfuscating the implementation of the material from the students.

Figure 1. Multimedia with and without social persuasion prompts

Conversely, Figure 2 illustrates the discrepancy in social persuasion prompts present in printed materials. In the social persuasion prompt treatment, students are exposed to motivational language from a familiar figure in this research, Albert Einstein, prior to being acquainted with the learning objectives. The prompts included mastery experiences and vicarious experiences and verbal persuasion presented were for a correct response (such as “Good work”. “Your effort paid off”. “Keep it up!”) and an incorrect response (“Your answer is not 100% correct”. “Don’t give up”. Focus on the next example-problem pair. Study the example carefully”. With hard work, “you can improve your performance”.). In other words, participants received one of the two messages in each effort feedback pair for each problem, depending on whether they solved the problem correctly or incorrectly. The printed version of the worked example of persuasion prompts is the same as the multimedia version, but in the printed version, it is written in each part of the worked example, accompanied by an image of Albert Einstein who seems to be the one giving the verbal persuasion.

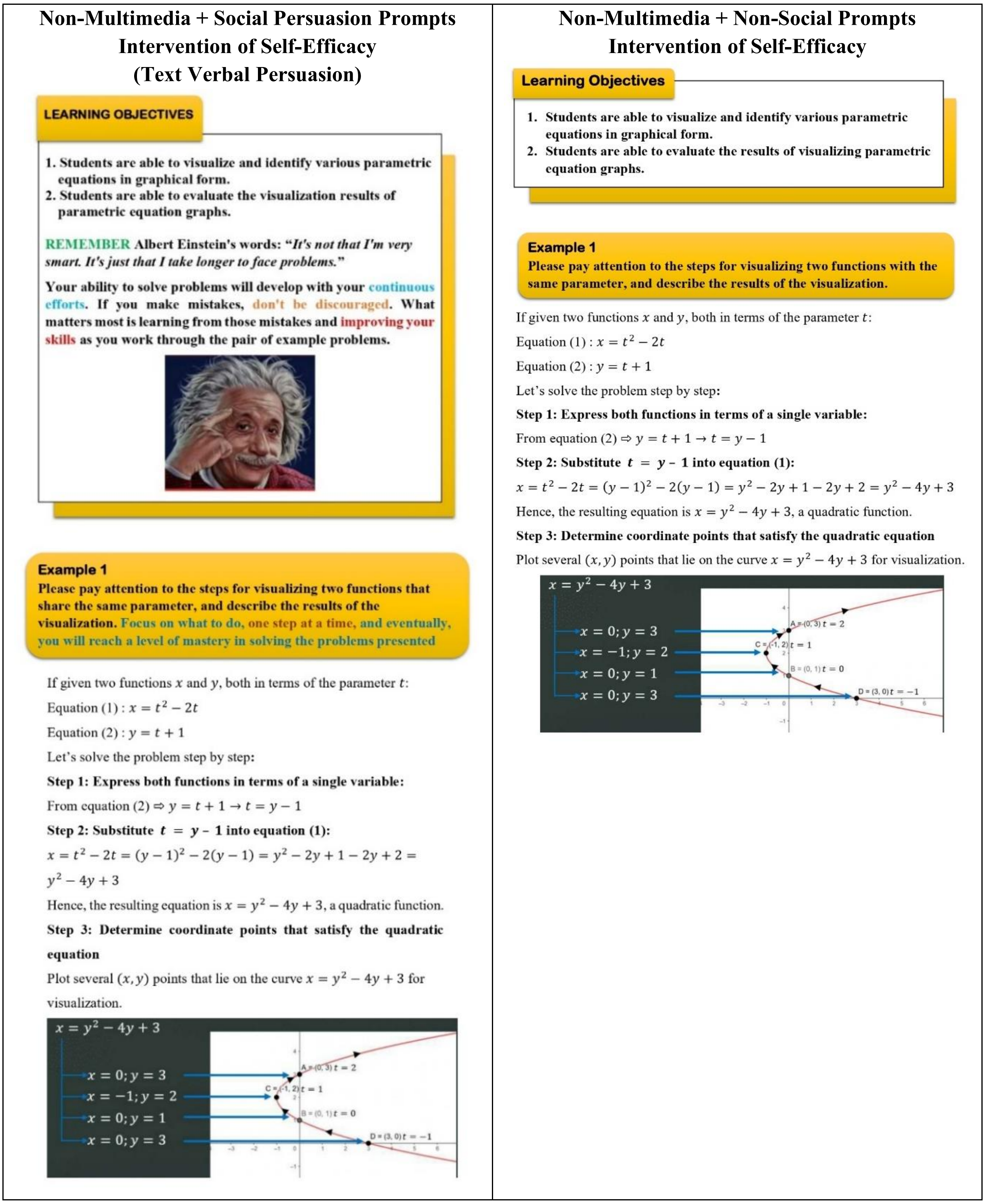

Figure 2. Printed material with and without social persuasion prompts

Experiment Procedure

Each group had the same three phases: the introductory phase (10 minutes), the acquisition phase (20 minutes), and the test phase (25 minutes), except that the multimedia groups were asked to study using multimedia and the others using printed booklets. Each group was characterized by: multimedia with social persuasion strategy, multimedia without social persuasion strategy, non-multimedia with social persuasion strategy, and non-multimedia without social persuasion strategy.

In the acquisition phase, students did material apperception and learned worked examples through the LMS. After that, students entered the test phase by completing problem-solving tasks. After they finished working on each problem, they filled in the self-rating forms for self-efficacy and cognitive load. For each stage of the LMS, students could not skip; but they worked in the order of apperception, viewing the multimedia (in this case, worked examples delivered with pedagogical agents could be viewed repeatedly with the back and next button menu), and filling in the self-rating forms. The two non-multimedia groups answered the questions and completed the self-rating on paper, while the multimedia group filled in the LMS, which was integrated into the Google form.

The test used a problem-solving item on parametric equations in the multivariable calculus course. The test is divided into the following sections: an introductory phase of six minutes, an apperception phase of seven minutes, a test phase of 20 minutes, and a closing phase of three minutes. It is important to note that this time allotment does not include the time to fill in the self-rating of the cognitive load and self-efficacy, which are three minutes each. To evaluate the efficacy of social persuasion prompts on multimedia versus non-multimedia formats, the researchers employed a control group absent from social persuasion.

Instruments

There were three measurements in this experiment. First, for the cognitive load measure from Paas and Sweller (2014), the nine-point Likert scale was used. The scale contains questions about how difficult it is for participants to solve the problems presented, and they write down a scale of 1-9, with the scale of 1 representing very easy and 9 representing very difficult.

Second, for measuring self-efficacy levels, a task version of Bandura's self-efficacy measure was used (Bandura, 1997). The question is, "How confident are you that you can determine the value of t based on taking any value of x and y from the existing parametric equation?" The scale of the answer is 10% – 100%, 10% being very unsure and 100% being completely sure.

Lastly, for measuring student achievement on problem-solving ability, a standardized problem-solving test item was given, a test-transfer item to 'evaluate and sketch a curve using the following parametric equation'. The scale reliabilities (Cronbach's α) were 0.92. Furthermore, one of the problems proposed in this study, as follows:

Show with an arrow that the curve formed is an ascending curve.

$$x = t^2 + t, \quad y = t^2 - t, \qquad -2 \leq t \leq 2$$

The problem-solving questions are presented in the LMS, and students are given 20 minutes to complete them, with a maximum score of 100.

Data Analysis

Data were analyzed using both descriptive and inferential statistical techniques. An independent samples t-test was first conducted to examine potential differences in pre-test scores between materials characterized by high and low element interactivity, ensuring equivalence between groups before the intervention. Subsequently, a series of one-way and two-way ANOVA were employed to investigate the main and interaction effects of the experimental conditions—namely instructional modality (multimedia vs. non-multimedia) and social persuasion prompts (printed vs. non-printed)—on the dependent variables. These included cognitive load, measured by the Data Filling Cognitive Load Scale; self-efficacy, assessed through a task-specific self-efficacy instrument based on Bandura's framework; and learning achievement, evaluated through a standardized problem-solving test on parametric equations. Statistical analyses were conducted using appropriate software, with a significance level set at $\alpha = 0.05$ to determine the presence of statistically significant differences across conditions.

RESULTS AND DISCUSSION

This study examines the impact of verbal persuasion prompts delivered in multimedia versus non-multimedia instructional modes on students' self-efficacy, academic achievement, and cognitive load in the context of advanced mathematics learning. Specifically, it investigates whether the integration of verbal persuasion—operationalized as social persuasion prompts—within multimedia learning environments yields greater benefits compared to non-multimedia formats. Additionally, the study explores the influence of the absence of such prompts across both modes, aiming to determine whether the lack of intervention differentially affects learners' self-efficacy, performance outcomes, and perceived cognitive load. The findings related to each of these dimensions are presented in the following sections.

Preliminary Results

Analysis of achievement was conducted using a covariate ($F(1, 53) = 9.794$, $p = 0.003$, $\eta^2 = 0.156$. The findings suggest an insignificant difference between groups (With and Without the variable) regarding achievement, as the means for both groups are roughly comparable. The "With" group had a mean (M) = 71.778 and a standard deviation (SD) = 4.475, and there were 27 participants in that group. The "Without" group had a mean (M) = 71.931 and a standard deviation (SD)= 4.382, and there were 29 participants in that group. Cognitive Load (CL) showed that the covariates contributed to was significantly ($F(1, 53) = 34.766$, $p = 0.001$, $\eta^2 = 0.396$). The "Without" group obtained higher scores on a cognitive load measure, which suggests that having a specific trait may lower cognitive load. The "With" group had an average (M) = 3.556 (SD = 1.251), while the "Without" group had an average (M) = 5.517, (SD = 1.214).

The presence or absence of self-efficacy was a significant impact on self-efficacy (F(1, 53) = 23.308, $p < 0.001$, $\eta^2 = 0.305$), with the "With" group showing a higher mean self-efficacy score (M = 74.888, SD = 9.637, n = 27) compared to the "Without" group (M = 62.918, SD = 9.070, n = 29). Moreover, for the Multimedia Results: Achievement suggested that multimedia created a substantial impact on achievements (F(1, 63) = 45.699, $p < 0.001$, partial $\eta^2 = 0.420$). The "With" group, which used multimedia, had a better average achievement score (M = 90.485, SD = 11.226, n = 27) than the "Without" group (M = 71.872, SD = 5.832, n = 39). Furthermore, Cognitive Load on Multimedia: Similar to the previous findings, the "With" multimedia group showed a lower cognitive load (M = 3.333, SD = 1.568, n = 27) in comparison to the "Without" multimedia group (M = 5.539, SD = 1.315, n = 39). The effect was significant (F(1, 63) = 37.381, $p < 0.01$, partial $\eta^2 = 0.372$). Finally on Self-Efficacy: Multimedia substantially impacted self-efficacy (F(1, 63) = 20.847, $p < 0.001$, partial $\eta^2 = 0.249$), with the "With" multimedia group practicing greater self-efficacy (M = 75.778, SD = 9.956, n = 27) in contrast to the "Without" group (M = 65.478, SD = 8.019, n = 39).

Investigation shows that the presence of specific components, including multimedia and other interventions, significantly enhances student achievement, cognitive load, and self-efficacy. The findings indicate that multimedia specifically improves student achievement across all three areas, while reducing cognitive load and boosting self-efficacy. Table 1 highlights significant differences in the delivery of social persuasion prompts for cognitive load, self-efficacy, and students' achievement. Nevertheless, multimedia and non-multimedia formats exhibit no major differences in cognitive load, self-efficacy, and student achievement.

Table 1. Group means and standard deviations of each group treatment

	Social Persuasion Prompts				Media			
	Without (n=68)		With (n=54)		Multimedia (n=66)		Non-Multimedia (n=56)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Cognitive Load	5.53	1.263	3.44	1.410	4.64	1.786	4.57	1.571
Self-efficacy	64.39	8.513	75.33	9.176	69.69	10.163	68.69	11.055
Student Achievement	71.90	5.227	81.13	12.679	79.48	12.462	71.86	4.388

The presence of social persuasion significantly reduces cognitive load, as evidenced by the value $p < 0.001$. The average cognitive load without social prompts is (*M* = 5.53), while the average with social prompts is (*M* = 3.44), indicating a decrease in cognitive load when social persuasion is being used. Moreover, self-efficacy indicated a significant difference ($p < 0.001$), represented by an average self-efficacy score without social persuasion (*M* = 64.39) compared to an average self-efficacy score with social persuasion (*M* = 75.33).

Additionally, student achievement, specifically problem-solving ability, showed a significant difference with social persuasion prompts ($p < 0.001$) (*M* = 81.13), in contrast to the average student achievement without comparable prompts (*M* = 71.90). In the media group, including both multimedia and non-multimedia, cognitive load ($p = 0.719 > 0.05$) and self-efficacy ($p = 0.274 > 0.05$) indicate no significant differences. Table 1 reveals that for the dependent variable cognitive load, multimedia (*M* = 4.64) and non-multimedia (*M* = 4.57) show no significant difference.

Similarly, for the dependent variable self-efficacy, the average scores are (*M* = 69.69) for multimedia and (*M* = 68.69) for non-multimedia, indicating no significant difference. In the dependent variable of student achievements, multimedia shows a significant difference (*M* = 79.48) compared to the non-multimedia treatment (*M* = 71.86). Eventually, across the media group, only the dependent variable of student achievement showed a significant difference.

In addition to this, the findings can be observed statistically, and the outcomes of each variable can be given in the following manner.

Social Persuasion Prompts in Multimedia Learning Significantly Reduce Cognitive Load

Within each of the four groups, the factorial design ANOVA showed that there were significant differences in the scores of the cognitive loads. It was found that participants in the group that used multimedia with an integrated self-efficacy (i.e., social persuasion prompts) reported the lowest cognitive load, while participants in the group that did not use multimedia and did not have self-efficacy reported the highest cognitive load. Comparisons made after the fact revealed that there were considerable variations among the groups. Statistically significant differences were found in the ANOVA shown in Table 2.

Table 2. Effects on cognitive load

Variables	Means of Squares	df1	df2	*F*	Sig.	η^2
Multimedia-Type	0.301	1	118	0.168	0.001	0.683
Self-Efficacy Aspect	129.379	1	118	72.149	0.000	0.379
Interaction Effect	0.442	1	118	0.246	0.621	0.002

The impact of multimedia, encompassing both multimedia and non-multimedia components, on cognitive load reduction was examined in Table 2. The analysis yielded a partial eta squared was 0.683, indicating a substantial impact. Additionally, the study investigated the role of self-efficacy in reducing cognitive load. The intervention, incorporating verbal persuasion prompts, demonstrated a significant impact with a partial eta squared was 0.379. This finding aligns with Sweller's (1988; 2023) cognitive load theory, which proposes that cognitive load is an important factor influencing learning efficiency. The cognitive learning theory asserts that the cognitive capacity of humans is finite and that instructional approaches ought to strive to maximize the utilization of this limited capacity to improve learning conditions.

Mayer (2021) explains that multimedia learning is consistent with this principle because it processes information through both audio and visual channels. This means that it has the potential to reduce cognitive overloads when it is structured effectively. When compared to non-multimedia learning environments, the study found that multimedia learning environments tended to lower extraneous cognitive loads, which is defined as the mental effort necessary to understand information that is either irrelevant or poorly structured. This is supported by Mayer's (2021) multimedia principle, which states that presenting information in both visual and audio modes helps learners receive and retain knowledge more effectively, this data lends support to the theory. On the other hand, the findings suggested that the utilization of multimedia learning alone (Group 2: MM – SP) does not necessarily result in the most effective decrease of cognitive loads. This indicates that, although learning through multimedia is beneficial, it might not be adequate on its own to address the germane cognitive load that is intrinsic (Sweller, 2020). The term "intrinsic cognitive load" refers to the inherent difficulty of the material itself, whereas the term "germane cognitive load" refers to the mental effort necessary for processing and integrating new information (Paas & Sweller, 2014). Consequently, when self-efficacy interventions are paired with multimedia learning (Group 1: MM + SP), it has the potential to ease both intrinsic and germane cognitive demands. This is accomplished by boosting learners' confidence in their capacity to understand the topic.

Key findings concerning lower cognitive load with integrated strategy can be reported as follows: The integrated strategy (IS) imposes a significantly lower cognitive load compared to the non-integrated strategy (NIS). This is consistent with the cognitive load theory (Sweller, 1988; 2020), which emphasizes the importance of instructional strategies that reduce unnecessary cognitive demands and optimize learning processes. Concerning the impacts of multimedia on cognitive load, both strategies benefited from the inclusion of multimedia, as evidenced by the slightly lower cognitive load in the multimedia (M) condition. This finding is aligned with the multimedia learning theory (Lawson & Mayer, 2024; Mayer, 2021; 2014; Mukanova et al., 2024), which posits that multimedia tools enhance learning by effectively integrating visual and verbal information, thereby reducing extraneous cognitive load. In contrast, cognitive load increased for both strategies in non-multimedia (NM) environments, although the integrated strategy remained more efficient.

Social Persuasion Prompts in Multimedia Learning Have a Significant Impact on Self-Efficacy

Incorporating self-efficacy treatments into a multimedia learning environment appeared to alleviate cognitive strains. This is most likely because the interventions provided students with a sense of control and confidence, which enabled them to be engaged with the learning material more effectively. The multimedia format likely made the information processing easier, which comprised both visual and audio components. This multimedia presentation resulted in a reduction in the overall cognitive obligation. On the other hand, Group 2 (MM-SP), which did not include any self-efficacy interventions and merely utilized multimedia learning, reported a higher cognitive load. This implies that, even while multimedia may offer numerous modalities of information transmission, the lack of self-efficacy support may leave learners feeling less confident, which causes them to view the activity as being more difficult than it is.

Similarly, the reason that Group 3 (Non-MM + SP) displayed a moderate cognitive load is probably due to the fact that, even though they had access to self-efficacy interventions, the non-multimedia learning format (such as text or static content) was less engaging and demanding in terms of cognitive processing. In conclusion, the group that reported the highest cognitive load was Group 4 (Non-MM-SP), which did not receive any interventions involving either self-efficacy or multimedia. Learners were unable to effectively comprehend the material since there were no multimedia materials available, and there were also no strategies that could boost their confidence or motivation.

Furthermore, there was a substantial difference in the levels of self-efficacy among the groups. The group that utilized multimedia with integrated self-efficacy received the best score, in contrast to the group that did not utilize multimedia and did not incorporate self-efficacy, which received the lowest score. The analysis of variance revealed substantial differences, as clearly shown in Table 3.

Table 3. Effects on self-efficacy

Variables	Means of Squares	df1	df2	*F*	Sig.	η^2
Media-Type	2590.325	1	118	54.314	0.000	0.315
Self-Efficacy Aspect	2538.340	1	118	53.224	0.000	0.311
Interaction Effect	2623.351	1	118	55.006	0.000	0.318

The data, as clearly shown in Table 3, indicate that both the main effects and the interaction effect of Media-Type and Self-Efficacy Aspect are statistically significant and practically impactful, with a large effect size. This suggests that these variables are important drivers of the variation in the dependent variable, and their influence is not trivial. Media-Type with F-value = 54.314 and $p = 0.000$ indicates a significant effect of Media-Type on the dependent variable because the p-value is below the conventional threshold of 0.05. The F-statistic is quite large, suggesting a strong distinction between the groups based on Media-Type. Similarly, the Self-Efficacy Aspect with $F = 53.224$ and $p = 0.000 < 0.001$ indicates a statistically significant main effect on the dependent variable. The F-statistic here is also large, which means that the variation due to this variable is substantial. The Interaction Effect with $F = 55.006$ and $p = 0.000 < 0.001$ means the interaction effect between Media-Type and Self-Efficacy Aspect has a significant impact on the dependent variable as well. The high F-value indicates that the combined effect of the two variables leads to a significant difference.

Moreover, Partial Eta Squared values between 0.311-0.318 are generally considered large effect sizes, meaning each variable explains about 31% to 32% of the variance, which is quite substantial. All three main effects (Media-Type, Self-Efficacy Aspect, and Interaction Effect) have a statistically significant impact on the dependent variable (p-values all < 0.05). The Interaction Effect has a slightly higher F-value (55.006) than the individual main effects, which suggests that the combined effect of Media-Type and Self-Efficacy Aspect is slightly stronger than the independent effects of these variables. These findings confirm that self-efficacy prompts integrated into multimedia learning environments significantly enhance learners' self-efficacy, thus supporting Hypothesis 2.

Furthermore, Figure 3 illustrates a profile plot of the estimated marginal means of self-efficacy, comparing two groups (integrated strategy [IS] and non-integrated strategy [NIS]) across two media types (multimedia [M] and non-multimedia [NM]). Concerning self-efficacy levels by media types and strategies, the integrated strategy (IS) group exhibits a significant difference in self-efficacy levels between the multimedia (M) and non-multimedia (NM) contexts. As shown in Figure 3, specifically, in the multimedia (M) context, the mean self-efficacy is significantly higher (around 90) while, in the non-multimedia (NM) context, the mean self-efficacy drops substantially (around 70). This steep decline, visible in the slope of the IS line, suggests that the Integrated Strategy (IS) is much more effective when multimedia is utilized. The non-integrated strategy (NIS) group shows almost no variation in self-efficacy between the two media types. Self-efficacy levels remain relatively stable (around 70), regardless of the types of the media used.

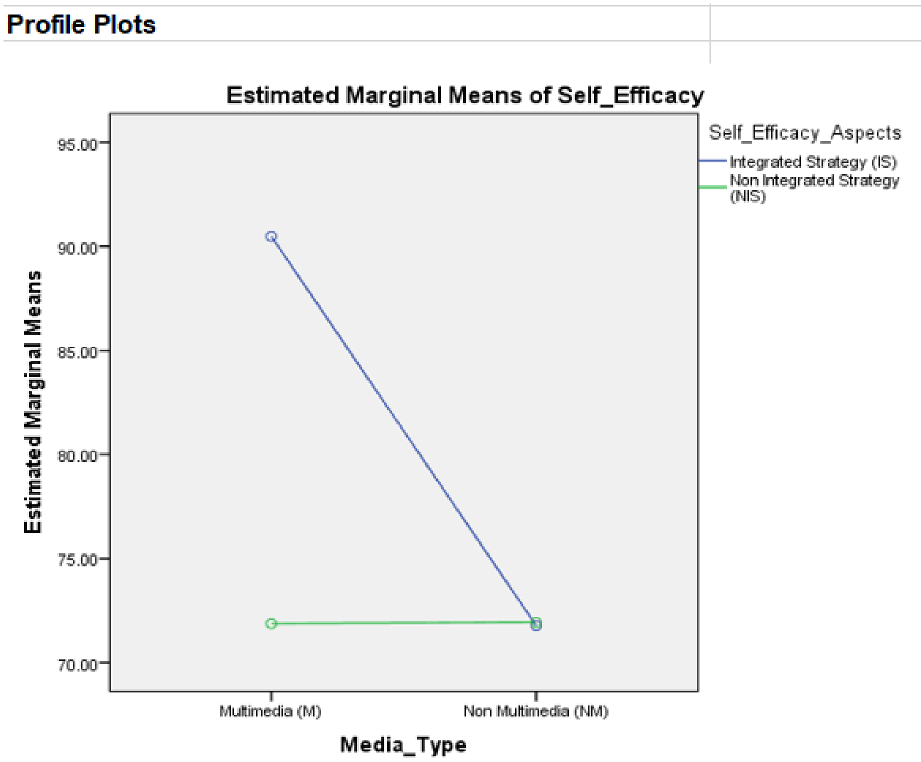

Figure 3. Interaction effect on self-efficacy in multimedia

Hence, a significant interaction exists between media types (M vs. NM) and strategies (IS vs. NIS). This interaction is visualized in the divergent slopes; the steep slope for IS indicates that this strategy's effectiveness is highly dependent on multimedia. Meanwhile, the nearly flat slope for NIS indicates that this strategy is not influenced by the types of media used.

Self-efficacy, which exhibits a considerable improvement for those who receive integrated interventions within multimedia, has the most important and significant outcome that is obtained. Self-efficacy is important not just because it helps motivate learners to take chances and keep trying, but also because individuals who have self-efficacy (the perception that they have some control over their learning) believe that they will learn effectively if they put in sufficient effort.

As evidenced by significantly higher stiles and overall performance in participants assigned the multimedia plus integrated self-efficacy, this is consistent with previous research that has found self-efficacy beliefs to be a significant predictor of academic achievement (Schunk, 1991; Zimmerman, 2000). This is something that has been found to be the case.

Participants in the non-multimedia groups who were given self-efficacy interventions, on the other hand, did not manage cognitive load as effectively as those who were given multimedia interventions, nor did they perform as well as those who were given multimedia interventions, i.e., social persuasion. In light of this, it may be deduced that interventions that are focused on the promotion of self-efficacy, while valuable when conducted on their own, are more effective when combined with multimedia materials. According to Pajares (1996), the combination of the two aspects assists in illustrating more successful strategies and outcomes, so increasing their firm sense of self-efficacy.

Social Persuasion Prompts in Multimedia Learning through Positive Feedback Have a Greater Impact on Student Achievement

The use of multimedia results in higher student achievement for both strategies. Integrated Strategy (i.e., with social persuasion prompts): higher students' achievement (M = 75). Non-Integrated Strategy (i.e., without social persuasion prompts): moderate achievement (M = 65). The transition to non-multimedia (NM) reduces students' achievement for both strategies, but the decline is more significant for NIS (from M = 65 to M = 62.5). The integrated strategy shows only a slight decrease in students' achievement when transitioning from multimedia to non-multimedia. This stability indicates that the motivational effects of positive feedback embedded in social persuasion help buffer against performance drops even in less dynamic learning environments. In contrast, the non-integrated strategy demonstrates a sharper decline, indicating that this strategy is more dependent on the presence of multimedia for better performance.

As key findings of the effectiveness of integrated strategies, the integrated strategy (IS) results in significantly higher student' achievement across both media types. The smaller decline in performance for IS in non-multimedia settings suggests that the use of social persuasion—particularly in the form of positive feedback—supports sustained motivation and problem-solving performance.

There are limitations in the non-integrated strategies. The non-integrated strategy (NIS) is less effective overall and is particularly vulnerable in non-multimedia environments, as evidenced by the sharper decline in students' achievements. This aligns with research suggesting that motivational and contextual supports—like those embedded in social persuasion prompts—are critical for maintaining engagement and achievement in challenging tasks (Mayer, 2021).

The group that utilized multimedia with integrated self-efficacy, i.e. social persuasion, obtained the highest scores, whereas the group that did not utilize multimedia and did not incorporate self-efficacy received the lowest marks. This suggests that the inclusion of motivational elements such as positive feedback enhances students' belief in their competence, which translates into improved performance. Statistically significant differences were found in the ANOVA shown in Table 4.

Table 4. Effects on student achievement

Independent Variables	Means of Squares	df1	df2	*F*	Sig	η^2
Media-Type	88.671	1		1.074	0.302	0.009
Self-Efficacy Aspect	3695.500	1		44.775	0.000	0.275
Interaction Effect	20.789	1		0.252	0.617	0.002

The analysis suggests, as shown in Table 4, that Self-Efficacy Aspect is the most important factor influencing student achievement, with both a statistically significant effect and a moderate to large effect size. The self-efficacy aspect has a partial eta squared value of 0.275, a moderate to large effect size, showing that it substantially influences student achievement.

Moreover, the self-efficacy aspect is the only variable with a statistically significant effect on student achievement, and it also has a large *F*-statistic (44.775), indicating that it plays a major role in explaining student achievement, i.e., problem-solving ability. Self-efficacy aspect is the most important factor in predicting student achievement, both statistically and practically. This confirms that students' belief in their capability, which is reinforced through social persuasion and positive feedback, directly contributes to their academic success.

Media type has no significant effect on achievement, implying that it is not a crucial variable in improving academic outcomes. The interaction effect between Media-Type and Self-Efficacy is also insignificant, suggesting that these two variables do not combine to offer any additional explanatory power. Therefore, educational strategies should emphasize enhancing students' self-efficacy—especially through timely and relevant positive feedback within multimedia environments—while considering Media-Type as a secondary factor.

In this study, we identified preliminary evidence that multimedia learning, conceptualized based on the principles of cognitive load theory and augmented with self-intervention strategies in social persuasion prompts, exhibited a reduction in cognitive load, an augmentation in self-efficacy, and a substantial increase in student achievement, particularly in the domain of learning parametric equations in calculus courses. These findings directly support Hypotheses 1, 2, and 3, demonstrating the significant benefits of multimedia enriched with social persuasion prompts strategies.

This study is the first experimental investigation to examine whether pre-service mathematics teachers learning mathematics using multimedia supplemented with social persuasion experience reduced cognitive load, increased self-efficacy, and improved student achievement. It is noteworthy that student participation in this study occurred exclusively in an offline classroom setting, yet they utilized an LMS to access the multimedia content. Conversely, the other experimental group was instructed through paper-based materials that employed the same worked example design as the multimedia presentation. This ensures that differences in outcomes are attributable to the media type and the presence of social persuasion prompts.

The findings of this study are consistent with the findings of prior research. As for the importance of multimedia, both strategies benefit from the use of multimedia, but the impact is more pronounced for the non-integrated strategy. This is consistent with the cognitive theory of multimedia learning (CTML), which posits that multimedia tools help learners integrate verbal and visual information, enhancing understanding and performance (Mayer, 2021). In the interaction effects, the interaction effect between media types and strategies highlights the importance of tailoring instructional strategy to the tools available. Multimedia environments are particularly beneficial for less effective strategies, such as NIS, as they compensate for some of the strategy's limitations. Thus, this finding reinforces the value of multimedia especially when integrated with motivational supports, as stated in Hypothesis 1.

For example, for leverage of multimedia for NIS, educators relying on non-integrated strategies should prioritize the use of multimedia to mitigate its limitations and improve students' achievement. Interactive and multimedia-based instructional designs could help bridge the gap between the two strategies. When compared to all of the components in both of the groups as mentioned above, the participants who participated in the multimedia learning with social persuasion prompts reported the lowest germane load. This further validates Hypothesis 1, confirming that social persuasion embedded in multimedia reduces cognitive load significantly.

This study's finding is aligned with the theories that have been investigated on multimedia learning, which are based on cognitive learning psychology. These theories claim that high-quality multimedia presentations can lower the amount of redundant loads that learners experience by allowing them to comprehend information visually and aurally. According to Moreno and Mayer (2000), dual coding, which involves the integration of both visual and auditory information, makes it possible to process information more quickly. In light of this, the multimedia environment does not only encourage cognitive processing; rather, it also appears to increase the level of material engagement.

The Impact of Multimedia with Social Prompt's Intervention on Cognitive Load, Student Achievement, and Students' Self-Efficacy

Self-efficacy, as described by Bandura (1997), is the belief that an individual has the capacity to effectively complete a task. A cognitive load, on the other hand, is the amount of work one has to do.

Self-efficacy beliefs are said to affect the cognitive, emotional, and behavioral processes that are involved in the learning process, at least according to the social cognitive theory.

The present findings support Hypothesis 1 by showing that social persuasion prompts embedded in multimedia reduce cognitive load. It has been demonstrated through the findings of the present study that therapies aimed at enhancing self-efficacy have the potential to dramatically lessen cognitive loads, particularly when applied to complex multimedia content. The learners who were given self-efficacy interventions (Groups 1 and 3) reported reduced levels of cognitive anxiety and higher levels of motivation to engage with the subject that they were learning.

Bandura's (1997) self-efficacy theory presents that high self-efficacy beliefs help learners to approach learning activities with greater tenacity and confidence, minimizing the mental work necessary to engage with complex information (Zimmerman, 2000). These findings are consistent with the theory. For learners using integrated strategies, incorporating multimedia tools can significantly boost self-efficacy, motivation, and, ultimately, performance. This is supported by prior studies that highlight multimedia as a catalyst for cognitive engagement (Mayer, 2021; Murtianto et al., 2022). Hence, combining multimedia with social persuasion yields a synergistic effect on cognitive load reduction. For strategic adaptation, Educators using integrated strategies should prioritize multimedia-enriched environments to maximize outcomes. Conversely, if multimedia is unavailable, alternative strategies may need to be explored. Rethinking the non-integrated strategies, the stable but lower self-efficacy observed with Non-Integrated Strategy suggests limited benefits. Future instructional designs should consider integrating elements of multimedia or other engagement-enhancing tools to improve outcomes.

The results showed that a self-efficacy intervention in the form of social persuasion prompts significantly increased student achievement in mathematics learning. This supports Hypothesis 3, which posits that social persuasion in multimedia learning through positive feedback significantly impacts achievement. In this study, student achievement was measured by problem-solving skills. There was a sharp increase in the experimental class compared to the control class that did not use social persuasion. This finding is consistent with previous research. Wang et al. (2020) found that multimedia combined with integrated strategies i.e. adding social persuasion prompts improved both cognitive and emotional outcomes for learners, with participants showing higher self-efficacy and reduced cognitive stress during problem-solving tasks. Mutlu-Bayraktar et al. (2019) demonstrated that multimedia interventions significantly reduce cognitive loads and increase student achievement, especially in STEM education, by simplifying complex contents and promoting interactive engagement.

Additionally, it appears that therapies that focus on self-efficacy contribute to the facilitation of the relevant cognitive load, which is essential for deep learning. Students are more likely to adopt active learning methods such as self-regulation and goal setting, which have been demonstrated to assist successful cognitive processing (Zimmerman, 1990). This supports Hypothesis 2 by confirming that social persuasion prompts in multimedia significantly enhance self-efficacy levels. This is because students' self-efficacy is increased, which increases the likelihood that students will adopt these strategies. According to Paas and Sweller (2014), students who were not part of the intervention groups (Groups 3 and 4) expressed higher degrees of irritation and helplessness when confronted with challenging contents. This likely led to an increase in the amount of superfluous cognitive load that they were experiencing. These findings underscore the importance of fostering self-efficacy through instructional interventions. It appears that incorporating self-efficacy interventions into multimedia learning settings may be able to assist learners in more efficiently managing the cognitive demands of content that was previously considered hard. Mayer (2021) reinforces the idea that dual-channel multimedia learning (visual and verbal) enhances working memory capacity and reduces unnecessary processing demands, leading to increased self-efficacy.

In examining the effects of self-efficacy interventions in relation to multimedia learning, the relationship was most noticeable in the group that included both elements (Group 1: MM + SE). This particular group of students had the least number of cognitive burdens and the most successful learning outcomes. This finding highlights the potential of combining self-efficacy interventions with multimedia learning in order to create an environment that is optimal for learning. While the self-efficacy components assist students in regulating their cognitive and emotional responses to challenging material, the multimedia components address extraneous cognitive loads by organizing contents in ways that align with human cognitive architecture. This results in a reduction in the amount of mental effort that was not necessary.

According to the results of the study, the control group (Group 4: Non-MM – SE), which did not receive any interventions related to self-efficacy or multimedia learning, reported the highest cognitive load and the lowest engagement. This particular group most likely had a high intrinsic cognitive load as a result of the non-multimedia format, which necessitates a greater amount of cognitive work in order to process and comprehend material that is complicated. The students' feelings of ineffectiveness and worry were further aggravated by the absence of self-efficacy interventions, which resulted in a higher amount of extraneous cognitive load. This demonstrates the significance of combining motivational treatments, such as self-efficacy strategies, with multimedia learning to support students in managing the cognitive demands associated with learning activities.

As a key finding in the importance of multimedia, the integrated strategy (IS) relies heavily on multimedia to boost self-efficacy. This aligns with research emphasizing the role of multimedia in enhancing engagement, comprehension, and self-efficacy in learning environments (Bandura, 1997; Mayer, 2021). The stark decline in self-efficacy for IS in non-multimedia contexts highlights the potential limitations of this strategy when traditional, non-multimedia tools are used.

Concerning the stability of non-integrated strategy (NIS), the relatively stable performance of NIS across both media types suggests that this strategy is less influenced by the mode of delivery. However, it also indicates a lack of significant improvement in self-efficacy, regardless of the media type. In the interaction effects, the interaction between media types and strategies underlines the critical role of aligning instructional strategies with appropriate tools. Multimedia serves as a facilitator for integrated strategies, while its absence significantly reduces the effectiveness of such approaches.

Even though the current study offers useful insights into the impacts of self-efficacy and multimedia learning interventions on cognitive loads, self-efficacy, and student achievement, there are a number of potential pathways for future research that could further one's understanding of these variables and how they interact with one another. In light of the findings of this study, the following are some topics that can be suggested for further exploration. Self-efficacy is a powerful motivational construct that connects to a number of desired students' achievements, including enhanced learning performance and reduced cognitive loads. Numerous research studies have shown the linkage between self-efficacy, anxiety, and learning performance (Huang & Mayer, 2016; Huang et al., 2020). The results of this study are outstandingly important. They emphasize that the use of social persuasion prompts can reduce cognitive loads and increase self-efficacy. The results of this study also support Bandura's (1997) notion of context-dependent benefits. Researchers have pointed out that "people weigh and combine information from the various sources to form self- efficacy judgments" (Schunk & Usher, 2012), and the relative influence of each source may differ depending on the contextual and circumstantial factors such as gender, ethnicity, task difficulty, and learning domain (Huang et al., 2020; Schunk & Usher, 2012).

Another key finding of this study is that using multimedia with integrated strategies has a positive impact on self-efficacy and reduces cognitive loads. This finding aligns with the study by Zheng et al. (2020), highlighting how multimedia tools, when combined with well-structured instructional strategies, foster increased engagement and confidence among learners, leading to higher self-efficacy levels. This is because multimedia environments allow learners to interact with materials in multiple formats (visual, auditory, and textual), enhancing comprehension and reinforcing learning outcomes. For example, Mayer's (2021) cognitive theory of multimedia learning (CTML) suggests that multimedia leverages both visual and verbal processing channels, helping learners build stronger mental models and reduce anxiety associated with complex tasks.

CONCLUSION

The findings of this study underscore the positive effects of multimedia-supported instruction integrated with self-efficacy intervention strategies—specifically, verbal social persuasion prompts—on students' academic achievement and perceived self-efficacy. While the incorporation of multimedia elements alone proved effective in reducing cognitive load, the addition of verbal persuasion strategies, although associated with increased cognitive demands, still resulted in measurable gains in both self-efficacy and academic performance compared to non-multimedia instruction without interventions. These results suggest that targeted self-efficacy interventions, when embedded within multimedia environments, can enhance the learning process by fostering deeper engagement and greater learner confidence. By thoughtfully combining multimedia features with motivational strategies, educators can design learning experiences that are not only cognitively efficient but also psychologically empowering, thereby supporting improved conceptual understanding and perseverance in learning. This study thus reinforces the pedagogical value of integrating cognitive and affective design principles in multimedia-based mathematics instruction.

Nevertheless, the generalizability of these findings is limited by the contextual and demographic characteristics of the participants, as well as by the specific nature of the multimedia and self-efficacy interventions employed. Individual learner differences—such as prior knowledge, cognitive preferences, learning styles, and sociocultural backgrounds—likely influence how students interact with and benefit from multimedia-enhanced learning environments. Future research should therefore examine the interaction between these individual differences and multimedia design features, with particular attention to the role of pedagogical agents, including voice characteristics (e.g., gender, familiarity, or sociocultural relevance) in shaping self-efficacy beliefs. Investigations that adopt a more personalized approach to multimedia design, informed by empirical insights into learners' diverse profiles, hold promise for advancing equitable and effective mathematics education. Expanding this line of inquiry may ultimately contribute to the development of adaptive digital learning systems that are both cognitively sound and motivationally responsive.

ACKNOWLEDGMENTS

The authors would like to express their sincere gratitude to the Directorate for Research, Technology, and Community Services (DRTPM), Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia, for funding this research through Contract Number: 072/E5/PG.02.00.PL/2024.

DECLARATIONS

Author Contribution	:	YHM	: Conceptualization, Writing - Original Draft, Methodology, Formal Analysis, and Investigation.
		ER	: Conceptualization, Writing - Review & Editing, Methodology, and Supervision.
		JH	: Conceptualization, Writing - Review & Editing, Validation, and Supervision.

Funding Statement : This research was funded by the Directorate for Research, Technology, and Community Services (DRTPM), Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia, with the Contract Number: 072/E5/PG.02.00. PL/2024.

Conflict of Interest : The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Additional Information : Additional information is available for this paper.

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