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Integrating canva-AI and deep learning approaches into interactive mathematics videos to enhance mathematical literacy and self-regulated learning in vocational education

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Abstract

Background: Mathematical literacy and self-regulated learning (SRL) remain significant challenges in Indonesian secondary education, as reflected in students' low PISA performance. Conventional teacher-centered instruction often limits students' opportunities to develop mathematical problem-solving skills, communication abilities, and learning autonomy. Therefore, innovative interactive learning media are needed to support meaningful and independent mathematics learning.

Aims: This study aimed to develop an interactive mathematics learning video on exponential functions by integrating Canva-AI and deep learning approaches and to evaluate its validity, practicality, and effectiveness in enhancing students' mathematical literacy and SRL in vocational education.

Method: This study employed a Research and Development (R&D) design using the ADDIE model, including Analysis, Design, Development, Implementation, and Evaluation stages. Data were collected through expert validation questionnaires, student practicality questionnaires, and pretest–posttest assessments of mathematical literacy and SRL. Data were analyzed using MANCOVA after fulfilling normality and homogeneity assumptions.

Results: The developed video achieved highly valid and highly practical categories. MANCOVA results revealed a significant simultaneous effect on students' mathematical literacy and SRL posttest scores ($p < 0.05$). The experimental group demonstrated better posttest performance than the control group.

Conclusion: The interactive mathematics video is valid, practical, and effective in improving vocational students' mathematical literacy and self-regulated learning through AI-assisted and student-centered learning.

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INTRODUCTION

Mathematical literacy has become one of the most important competencies required in the era of globalization and digital transformation because it enables individuals to understand, interpret, and apply mathematical concepts in various real-world situations. Mathematical literacy is not limited to the ability to perform calculations, but also includes reasoning, communication, interpretation, and problem-solving skills that are essential in everyday life and professional environments. At the secondary education level, mathematical literacy serves as a strong foundation for developing critical thinking, analytical abilities, and decision-making skills (Erdoğan, 2020; Sachdeva & Eggen, 2021; Q. Wang & Abdullah, 2024). Students who possess strong mathematical literacy are generally more capable of identifying problems, analyzing quantitative information, and formulating appropriate solutions based on mathematical reasoning. In vocational education,

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mathematical literacy is particularly important because students are expected to apply mathematical concepts to authentic workplace situations and technological developments (Bolstad, 2023; Brantlinger, 2022; Çakıroğlu et al., 2024; Wannapiroon et al., 2021). However, the mathematical literacy achievement of Indonesian students remains relatively low compared to international standards, indicating that many students still experience difficulties in applying mathematics contextually (Manfreda Kolar & Hodnik, 2021). This condition reflects the limited ability of students to formulate, employ, and interpret mathematics in meaningful situations beyond procedural calculations. One of the factors contributing to this issue is the continued implementation of teacher-centered instruction that emphasizes memorization and routine exercises rather than conceptual understanding and contextual exploration. Such instructional practices often reduce students' opportunities to actively participate in learning activities and develop independent problem-solving abilities. Therefore, innovative and contextual instructional strategies are needed to support the improvement of students' mathematical literacy in vocational education.

In addition to mathematical literacy, self-regulated learning has become another essential competency required in twenty-first-century education because students are expected to become independent and lifelong learners. Self-regulated learning refers to students' abilities to plan, monitor, manage, and evaluate their own learning processes in order to achieve academic goals effectively (Chang et al., 2023; Radović et al., 2024; Sirk, 2025; Vosniadou, 2020; Wolters & Brady, 2021; X. Xu et al., 2025). Students with strong self-regulated learning skills tend to demonstrate higher learning motivation, better persistence, and greater responsibility for their academic achievement (Sutarni et al., 2021; K. M. Xu et al., 2023). In vocational education, self-regulated learning is particularly important because vocational students must be able to adapt to rapidly changing workplace demands and technological developments. However, many students still rely heavily on teachers during the learning process and show limited initiative in independently managing their learning activities. Conventional mathematics instruction often provides insufficient opportunities for students to develop autonomy, reflective thinking, and independent learning habits. The development of digital learning technology has created opportunities to support self-regulated learning through multimedia and interactive learning environments (Carter Jr et al., 2020; Sui et al., 2024; Urbina et al., 2021). Interactive learning media can increase students' physical, cognitive, and emotional engagement by providing more flexible and meaningful learning experiences (Desai & Kulkarni, 2022; Ozkan Bekiroglu et al., 2022; Tsai et al., 2020; Wong & Hughes, 2023). Moreover, digital learning systems allow students to access learning materials repeatedly, learn according to their own pace, and participate more actively in the learning process. Therefore, the integration of interactive and technology-enhanced learning media into mathematics education is considered a promising approach for improving both mathematical literacy and self-regulated learning among vocational students.

The rapid advancement of educational technology and artificial intelligence has significantly transformed the design and implementation of instructional media in mathematics education. One of the emerging technologies widely used in education is Canva-AI, which provides opportunities to create interactive and visually engaging learning materials that are accessible to digital-native students (Del Moral-Pérez et al., 2024; Sirait et al., 2025). Interactive mathematics videos supported by Canva-AI can integrate animations, narration, simulations, and contextual problem-solving activities into a more meaningful learning experience. At the same time, the implementation of deep learning approaches in education emphasizes meaningful understanding, reflective learning, active engagement, and contextual application of knowledge rather than rote memorization. The integration of deep learning approaches with AI-assisted interactive videos has the potential to support conceptual understanding, learning autonomy, and students' active participation in mathematics learning (Awang et al., 2025). Previous studies have shown that interactive videos and

multimedia learning can improve students' engagement, motivation, and conceptual understanding in mathematics education (Barut Tugtekin & Dursun, 2022; Desai & Kulkarni, 2022; Uwineza et al., 2023). Other studies have also highlighted the growing role of artificial intelligence in supporting adaptive learning systems, personalized learning experiences, and student-centered instruction (Khalifeh et al., 2026; Strielkowski et al., 2025). Nevertheless, most previous studies have examined mathematical literacy, self-regulated learning, interactive multimedia, and AI-assisted learning separately rather than integrating these components into a single instructional framework. In addition, studies specifically integrating Canva-AI and deep learning approaches into interactive mathematics videos designed for vocational students remain very limited. Therefore, there is still a significant research gap regarding the development of AI-assisted interactive mathematics videos that integrate deep learning principles, contextual vocational mathematics content, and reflective learning activities to simultaneously improve mathematical literacy and self-regulated learning in vocational education.

Although previous studies have widely investigated mathematical literacy, self-regulated learning (SRL), interactive video learning, AI-assisted learning, and vocational mathematics education, these topics have generally been examined independently rather than through an integrated instructional framework. Research on mathematical literacy has primarily emphasized contextual problem solving, mathematical tasks, and classroom implementation strategies, while studies on SRL have mainly focused on online learning environments, mobile learning, and academic achievement (Bolstad, 2023; Hwang & Ham, 2021; Manfreda Kolar & Hodnik, 2021; Palalas & Wark, 2020; Wolters & Brady, 2021). In addition, interactive and video-based learning media have been reported to improve learner motivation, conceptual understanding, and engagement in mathematics education; however, these studies predominantly concentrate on general multimedia effectiveness without integrating AI-supported learning environments or vocational mathematics contexts. Recent research has also (Barut Tugtekin & Dursun, 2022; Kellems et al., 2020; Radović et al., 2024) highlighted the increasing role of AI-assisted learning in supporting adaptive and technology-enhanced education, particularly regarding students' perceptions, digital transformation, and AI-supported learning systems (Lai, 2021; Pham et al., 2023). Nevertheless, studies specifically integrating Canva-AI and deep learning approaches into interactive mathematics videos designed to simultaneously improve mathematical literacy and SRL among vocational students remain very limited. Furthermore, vocational mathematics education research has largely focused on curriculum development, STEM integration, and authentic contextual problems without emphasizing AI-assisted interactive learning media that promote autonomous and student-centered mathematics learning (Akgunduz & Mesutoglu, 2021; Brantlinger, 2022; Dalby & Noyes, 2022). Therefore, there remains a significant research gap regarding the development of AI-assisted interactive mathematics videos that integrate deep learning principles, contextual vocational mathematics content, and reflective learning activities to simultaneously support mathematical literacy and self-regulated learning in vocational education.

This study aims to develop an interactive mathematics learning video integrating Canva-AI and deep learning approaches for vocational high school students on exponential function material. The study also aims to examine the validity, practicality, and effectiveness of the developed learning media in improving students' mathematical literacy and self-regulated learning. The development process adopts a systematic instructional design model to ensure that the learning media are aligned with students' characteristics and vocational learning needs. The interactive learning videos are designed to provide contextual mathematical problems, reflective learning activities, and meaningful visual representations that encourage active student engagement. In addition, the integration of Canva-AI is expected to create more accessible, adaptive, and visually attractive learning experiences for vocational students. The deep learning approach implemented in the videos is intended to

encourage students to develop conceptual understanding and independent learning habits through meaningful learning activities. This study is also expected to contribute to the implementation of student-centered learning environments supported by artificial intelligence and interactive multimedia technology. Furthermore, the findings of this study are expected to provide practical recommendations for teachers and educational institutions regarding the use of AI-assisted instructional media in vocational mathematics education. The study also contributes theoretically to the growing discussion on integrating artificial intelligence, interactive multimedia, and deep learning approaches in mathematics education. Ultimately, this research seeks to support the development of innovative mathematics learning environments that improve students' mathematical literacy, self-regulated learning, and readiness for future workplace challenges in the digital era.

LITERATURE REVIEW

Mathematical literacy has become a central concept in contemporary mathematics education because it emphasizes students' ability to apply mathematical knowledge in authentic and contextual situations. Mathematical literacy is commonly understood as the capacity to formulate, employ, and interpret mathematics in various real-world contexts through reasoning, problem solving, and decision making (Bolstad, 2023; Manfreda Kolar & Hodnik, 2021). This competency supports students in understanding quantitative information, evaluating mathematical arguments, and communicating solutions effectively in both academic and professional environments. In vocational education, mathematical literacy is highly relevant because vocational students are expected to solve contextual workplace problems requiring analytical and mathematical reasoning skills (Bolstad, 2023). The development of mathematical literacy also contributes to students' readiness for lifelong learning and adaptation to technological changes in modern society. However, many students still experience difficulties in understanding contextual mathematical problems because classroom instruction often emphasizes procedural calculations rather than conceptual understanding. Consequently, mathematics learning frequently becomes disconnected from students' real-life experiences and professional needs. Several studies have suggested that contextual learning strategies and interactive instructional media can support the development of mathematical literacy more effectively. Interactive learning environments encourage students to actively construct knowledge through exploration, reflection, and problem-solving activities. Therefore, mathematical literacy requires instructional approaches that integrate contextual learning experiences, active student participation, and meaningful mathematical applications.

Self-regulated learning is another important concept in modern education because it reflects students' abilities to independently manage and evaluate their own learning processes. Self-regulated learning involves cognitive, motivational, behavioral, and emotional dimensions that influence students' academic achievement and learning persistence (Balashov, 2022; Estévez et al., 2021; Fong et al., 2024; Martin et al., 2022; Pérez-González et al., 2022; L. Wang, 2021; Wu et al., 2024). Students with strong self-regulated learning skills are generally more capable of setting learning goals, monitoring their progress, managing learning strategies, and reflecting on learning outcomes. In mathematics education, self-regulated learning plays an essential role because mathematical problem solving requires persistence, strategic thinking, and independent learning habits (Ansari et al., 2021; Munahefi et al., 2022; J. Wang & Guo, 2026). Students who possess self-regulated learning skills are more likely to actively seek solutions, review learning materials, and engage in reflective thinking during the learning process. However, conventional teacher-centered instruction often limits opportunities for students to develop autonomy and independent learning behaviors. Many students remain dependent on teachers' explanations and show limited initiative in

exploring mathematical concepts independently. The integration of digital learning environments and interactive multimedia has been recognized as an effective strategy for supporting self-regulated learning because students can access materials flexibly and learn according to their own pace. Technology-enhanced learning also provides opportunities for students to receive immediate feedback, monitor their performance, and participate more actively in learning activities. Therefore, self-regulated learning has become an essential competency that should be integrated into mathematics instruction to prepare students for lifelong learning and workplace adaptation.

Interactive learning videos have gained increasing attention in mathematics education because they provide more engaging, visual, and flexible learning experiences for students. Interactive videos combine audio, visual, animation, narration, and problem-solving activities into integrated instructional media that can improve students' understanding of mathematical concepts. Compared to traditional instruction, interactive learning videos allow students to revisit learning materials repeatedly according to their learning needs and preferences (Alwadei et al., 2020; Barut Tugtekin & Dursun, 2022; Desai & Kulkarni, 2022; Humphries & Clark, 2021). This flexibility helps students develop conceptual understanding and independent learning behaviors more effectively. Interactive videos also support contextual learning because mathematical concepts can be presented through authentic situations, simulations, and real-life applications (Puspitasari et al., 2024). In addition, interactive instructional videos can increase students' motivation and engagement by providing more attractive and student-centered learning experiences. Several studies have reported that interactive videos contribute positively to students' mathematical understanding, problem-solving skills, and learning participation. In vocational education, interactive videos are particularly useful because vocational students often require visual and contextual explanations connected to workplace situations. The use of interactive multimedia also supports differentiated instruction by accommodating diverse learning styles and learning speeds among students. Therefore, interactive learning videos represent an important instructional innovation capable of improving mathematics learning quality in vocational education environments.

The development of artificial intelligence in education has created new opportunities for designing adaptive and personalized learning environments that support students' learning needs more effectively. Artificial intelligence-based learning systems can provide personalized feedback, adaptive learning pathways, and interactive learning experiences that enhance student engagement and learning autonomy (Farhood et al., 2025; Hariyanto et al., 2025; Katalinic et al., 2026). One of the emerging technologies increasingly used in educational settings is Canva-AI, which supports the creation of interactive visual learning materials and multimedia instructional content. Canva-AI enables educators to design visually attractive learning videos by integrating animations, audio narration, interactive activities, and contextual illustrations into instructional media. The use of Canva-AI in mathematics learning has the potential to improve students' conceptual understanding by presenting mathematical concepts in more accessible and meaningful forms. Moreover, artificial intelligence-assisted learning environments can facilitate student-centered learning by allowing students to learn independently and interact actively with digital instructional materials. AI-assisted multimedia learning also supports reflective learning because students can review materials repeatedly and receive flexible access to learning resources. In addition, the integration of artificial intelligence into education aligns with current educational transformation trends emphasizing digital literacy and technology-enhanced learning. Nevertheless, the implementation of artificial intelligence in vocational mathematics education remains relatively limited compared to general education contexts. Therefore, further exploration regarding the integration of Canva-AI into interactive mathematics learning environments is necessary to support vocational students' mathematical literacy and self-regulated learning.

Deep learning approaches in education emphasize meaningful understanding, reflective thinking, active engagement, and contextual application of knowledge rather than memorization-oriented learning. Deep learning encourages students to construct understanding through exploration, analysis, reflection, and authentic problem-solving activities that promote higher-order thinking skills. In mathematics education, deep learning approaches are important because students are expected to understand mathematical concepts conceptually and apply them in diverse situations rather than merely memorizing formulas and procedures. The implementation of deep learning principles also supports students' autonomy because learners are encouraged to participate actively in constructing knowledge and evaluating their own learning progress. Vocational education particularly benefits from deep learning approaches because vocational students need contextual learning experiences connected to workplace environments and technological applications. The integration of deep learning principles into interactive mathematics videos can create more meaningful and student-centered learning experiences that support both conceptual understanding and learning autonomy. Interactive learning environments supported by deep learning approaches also encourage students to engage in reflective learning activities and collaborative problem solving. Furthermore, combining deep learning approaches with artificial intelligence-assisted multimedia can strengthen adaptive learning experiences by accommodating students' individual learning needs and learning characteristics. Despite the growing implementation of deep learning and AI-assisted learning in education, studies integrating these approaches into interactive mathematics videos for vocational students remain limited. Therefore, the integration of Canva-AI and deep learning approaches into interactive mathematics videos represents a promising instructional innovation for improving mathematical literacy and self-regulated learning in vocational mathematics education.

METHOD

Research Design

This research employed a Research and Development (R&D) design to produce interactive mathematics videos while evaluating their effectiveness in practice. Product development was carried out using the ADDIE model as a guiding framework consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation (Nurhayati et al., 2023). Success in each ADDIE stage serves as a prerequisite for proceeding to the next stage (Spatioti et al., 2022). The development process was integrated with expert reviews and iterative revisions, then tested through experimental field trials by comparing control and experimental classes. Thus, the product was comprehensively assessed, covering aspects of validity, practicality, and effectiveness. Based on the ADDIE framework, the Analysis stage was conducted by identifying needs through data collection in the form of interviews with teachers and students, observation of facilities and infrastructure as well as technological readiness, administration of initial ability tests, and review of curriculum documents and textbooks. The findings from this stage formed the basis for the Design stage, where the researcher developed a design for interactive videos on exponential material with the aim of improving students' mathematical literacy skills and Self-Regulated Learning. In the design stage, the researcher designed the flow and interactive activities in the learning video, prepared mathematical literacy questions, and compiled instruments to test the validity, practicality, and effectiveness of the learning video.

In the Development stage, the researcher realized the learning video design in accordance with the results of the needs analysis and the Design stage that had been carried out. Subsequently, the video was validated by experts until it was declared valid. After that, the product was tested on students to determine the level of practicality in its use. Based on feedback and trial results, the researcher conducted revisions until the product was declared valid and practical. After the learning

video was declared valid and practical, the next stage was Implementation, namely the use of the video in the experimental class to measure its effectiveness in improving students' mathematical literacy and Self-Regulated Learning. Furthermore, in the Evaluation stage, the researcher assessed the video's effectiveness based on test result data, then conducted final revisions to the product based on previous evaluation findings before the video was declared suitable for use. The entire development process using the ADDIE model is shown in Figure 1.

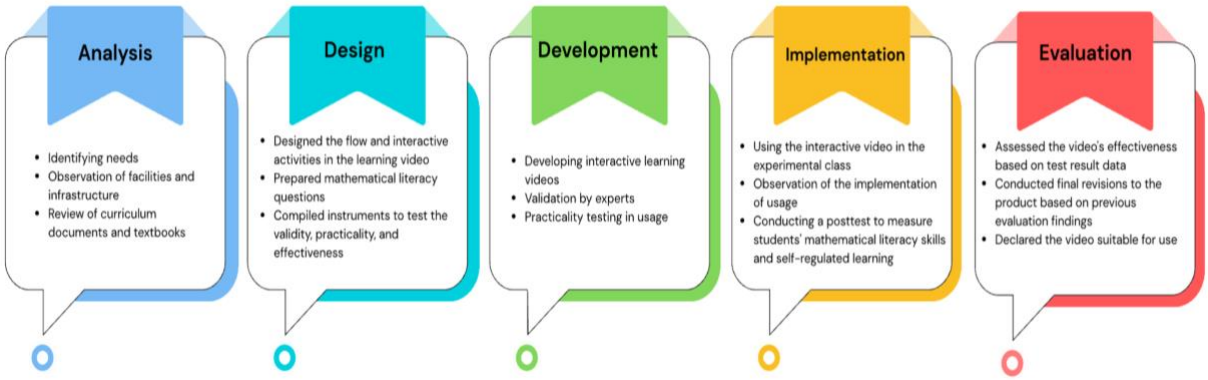


Figure 1. Implementation stage in developing interactive learning videos using the ADDIE model

Participants

The population of this study consisted of tenth-grade students in the Visual Communication Design (DKV) program at SMK Arya Singasari Larangan, Brebes Regency, in the 2025/2026 academic year. The sampling technique used was simple random sampling, with class X DKV 3 as the control group receiving conventional instruction and class X DKV 4 as the experimental group receiving treatment through interactive learning videos, with each group consisting of 30 students. The validation stage involved expert validators comprising lecturers and teachers for media and material validation. Furthermore, the practicality testing stage was conducted in class X DKV 2, which consisted of 30 students. The selection of the practicality testing class was carried out using purposive sampling, taking into account teachers' recommendations and supportive classroom conditions.

Instruments

Data were collected through questionnaires, written tests, observations, and interviews. The questionnaires were administered to measure students' Self-Regulated Learning (SRL) levels and to evaluate the validity and practicality of the interactive learning videos. Each questionnaire utilized a five-point Likert scale, where a score of 1 indicated "strongly disagree," 2 indicated "disagree," 3 indicated "somewhat agree," 4 indicated "agree," and 5 indicated "strongly agree." The SRL questionnaire was administered to students before and after the implementation of the research treatment to determine students' SRL levels under both conditions, and it included indicators for each phase of SRL as presented in table 1.

Table 1. Stages of Self-Regulated Learning

Stage	Indicator
Forethrought Phase	Setting learning goals and strategies
Performance Phase	Implementing the selected learning strategies, providing self-instruction to achieve learning goals, monitoring learning progress, and addressing challenges encountered during the learning process
Self-Reflection Phase	Evaluating and reflecting on learning outcomes, determining follow-up actions, and providing self-reward

At the validation stage, after the validators complete the questionnaire, a decision is made regarding the instrument's validity in accordance with the criteria in Table 2.

Table 2. Validation score categories

Percentage	Category
81 – 100	Highly Valid
61 – 80	Valid
41 – 60	Fairly Valid
21 – 40	Less Valid
0 – 20	Invalid

Based on table 2, the interactive learning videos are considered valid if the percentage of their validity scores exceeds 61%. Furthermore, to determine the level of practicality in the use of the interactive learning videos, the criteria presented in Table 3 are used as a reference.

Table 3. Practicality Test Questionnaire Score Categories

Percentage	Category
81 – 100	Highly Practical
61 – 80	Practical
41 – 60	Fairly Practical
21 – 40	Less Practical
0 – 20	Not Practical

Based on table 3, the interactive learning videos are considered practical if the average score of the practicality questionnaire exceeds 60%. To calculate the percentage scores of the validation and practicality test questionnaires, the following formula is used:

$$Percentage = \frac{\sum obtained\ score}{\sum maximum\ criterion\ score} \times 100\%$$

Written tests were administered to evaluate students' mathematical literacy skills before and after the treatment, which included indicators of mathematical literacy, namely formulating, employing, and interpreting (Fertikawati et al., 2025). Furthermore, the descriptions of these mathematical literacy indicators are presented in Table 4.

Table 4. Mathematical Literacy Indicators

Indikator	Description
Formulate	The ability to understand information from the given problems.
Employ	The ability to apply problem-solving strategies based on the information obtained.
Interpret	The ability to apply problem-solving strategies based on the information obtained.

Interviews were conducted to obtain preliminary data as a basis for developing the interactive learning videos. In addition, observations were carried out to collect supporting data and to provide a reference for evaluation throughout the research process.

Data Analysis

Data analysis in this study employed both qualitative and quantitative approaches to comprehensively evaluate the validity, practicality, and effectiveness of the developed interactive mathematics learning videos. Qualitative descriptive analysis was used to examine the findings obtained from interviews, classroom observations, expert suggestions, and students' responses during the development and implementation stages. The qualitative analysis aimed to identify instructional needs, evaluate the quality of the learning media, and support revisions throughout the development process. Quantitative analysis was conducted to evaluate the validity, practicality, and

effectiveness of the interactive learning videos. The validity and practicality data obtained from questionnaires were analyzed descriptively using percentage calculations based on the ratio between the obtained score and the maximum possible score multiplied by one hundred percent. The percentage scores were then interpreted according to predetermined validity and practicality criteria categories.

The effectiveness analysis focused on examining the impact of the interactive learning videos on students' mathematical literacy and self-regulated learning. Mathematical literacy scores and self-regulated learning questionnaire scores obtained from pretests and posttests were analyzed using Multivariate Analysis of Covariance (MANCOVA). MANCOVA was selected because the study involved two dependent variables analyzed simultaneously while controlling for pretest scores as covariates. Before conducting the MANCOVA analysis, prerequisite assumption tests were performed, including normality and homogeneity tests. The normality test was conducted using the Shapiro–Wilk test, while homogeneity of variance was evaluated using Levene's test. After the assumptions were fulfilled, MANCOVA analysis was performed to determine the simultaneous effect of the instructional treatment on mathematical literacy and self-regulated learning. In addition, follow-up tests using between-subject effects and pairwise comparisons were conducted to identify differences between the experimental and control groups for each dependent variable. The entire statistical analysis process was carried out using statistical software with a significance level of 0.05.

Procedure

The research procedure in this study followed the ADDIE development framework, which consists of five systematic stages: Analysis, Design, Development, Implementation, and Evaluation. In the Analysis stage, the researcher identified instructional needs related to mathematical literacy and self-regulated learning through interviews with teachers and students, classroom observations, analysis of technological readiness, and reviews of curriculum documents and instructional materials. Preliminary assessments were also conducted to identify students' initial mathematical literacy abilities and learning characteristics. The findings obtained during this stage served as the foundation for designing the interactive mathematics learning videos. In the Design stage, the researcher prepared the instructional flow, storyboard, interactive learning activities, mathematical literacy tasks, and self-regulated learning components integrated into the learning videos. The design process also included the preparation of research instruments consisting of validation questionnaires, practicality questionnaires, mathematical literacy tests, and self-regulated learning questionnaires. Furthermore, the researcher integrated Canva-AI features and deep learning principles into the instructional design to support meaningful and student-centered learning experiences.

During the Development stage, the interactive mathematics learning videos were produced based on the previously designed storyboard and instructional framework. The videos incorporated animations, narration, contextual mathematical problems, reflective learning activities, and interactive multimedia components developed using Canva-AI. After the product was completed, expert validation was conducted by lecturers and teachers specializing in mathematics education and instructional media. The validation process evaluated aspects related to media appearance, language clarity, instructional suitability, and mathematical content accuracy. Revisions were conducted based on experts' suggestions until the learning videos achieved acceptable validity criteria. Subsequently, a practicality test was carried out involving students outside the experimental and control groups to evaluate usability, attractiveness, clarity of presentation, and support for independent learning. Feedback obtained from the practicality test was used to improve the quality of the learning videos before implementation in the classroom.

The Implementation stage involved applying the developed interactive learning videos in the experimental class, while the control class received conventional mathematics instruction. Before the treatment, both groups completed pretests measuring mathematical literacy and self-regulated learning. The experimental class then participated in mathematics learning activities using the interactive videos integrated with Canva-AI and deep learning approaches. During the learning process, students engaged in contextual problem-solving activities, reflective learning tasks, and independent exploration through interactive multimedia features. Meanwhile, the control class received teacher-centered instruction using conventional learning methods. After the completion of the instructional treatment, posttests were administered to both groups to measure changes in mathematical literacy and self-regulated learning. Finally, the Evaluation stage was conducted by analyzing the results of the implementation process, identifying strengths and weaknesses of the developed media, and conducting final revisions to ensure the instructional product was appropriate for vocational mathematics learning environments.

RESULTS AND DISCUSSION

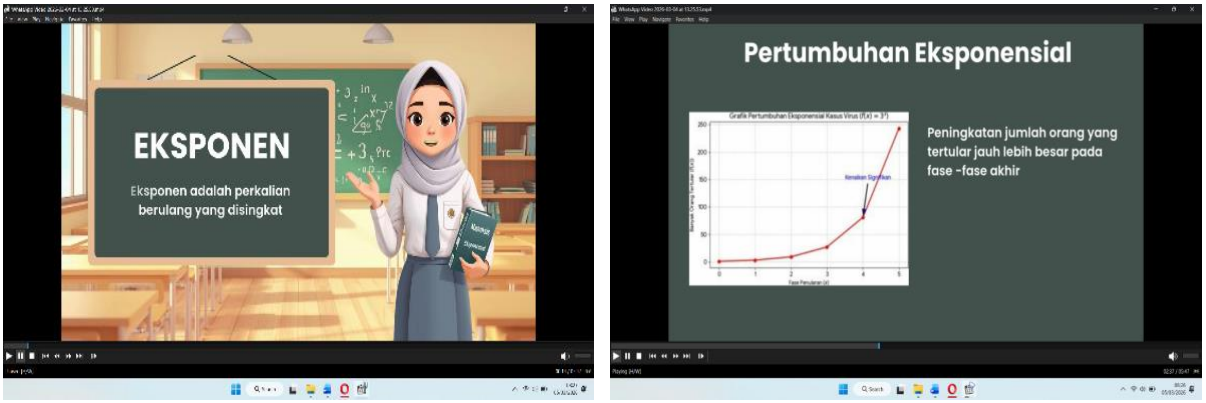
Results

Development result of the interactive mathematics video

When analyzing needs, the researchers found that the exponential material in the Merdeka Curriculum is well-structured; however, interactive media are not yet optimally used in teaching practice. Although schools have basic equipment such as computers, projectors/smart TVs, internet, and audio, these devices are still rarely and inefficiently used, so even though teachers and students have minimal access, they still need practical guidance to operate them. This limited infrastructure is directly related to findings from the initial tests and interviews, which showed varied abilities some students remain below the minimum competency threshold and many struggle to understand problems and manage their own learning (low SRL). In addition, the textbooks in use tend to be textual and insufficiently connected to the vocational contexts of vocational high school (SMK) students, making the need for media that links concepts to real-world contexts increasingly urgent. In the design stage, the researcher develops an interactive learning video on exponential functions supported by Canva-AI, with an emphasis on mathematical literacy and self-regulated learning (SRL). The design is built from the results of needs analysis and student characteristics, and it follows instructional design principles especially the cognitive theory of multimedia. The content is aligned with the learning outcomes of the Merdeka Curriculum and covers the meaning of exponents, exponent rules (multiplication, division, and zero/negative/fractional exponents), as well as real-life applications such as growth and decay, compound interest, and bacterial population models, using official references to ensure both procedural and conceptual accuracy. Canva-AI is used for templates, animations, voice-over, visual elements, and multimodal quizzes to reduce cognitive load, while ChatGPT helps generate interactive question ideas, drafts of scripts, contextual problems, and SRL reflection prompts. The PISA/OECD literacy content is arranged in increasing levels (low to high) and compiled into a question bank, and the evaluation instruments include validity (expert judgments on design/content/media), practicality (teacher and student questionnaires), and effectiveness (pre–post mathematical literacy tests and SRL questionnaires). The video follows a deep learning flow: a motivating opening linked to real-world goals, step-by-step presentation with misconception-targeting animations, interactive activities (quizzes, simulations, reflections), and a closing section with summaries and independent practice.

In the development stage, the interactive learning video based on Canva-AI was produced according to the storyboard and script prepared in the design stage. All media components such as the videos, animations, illustrations, audio, and interactive features were created using Canva-AI

with support from ChatGPT. As a result, the exponential material is presented in a more engaging and relevant way, following a deep learning approach to support students' mathematical literacy and self-regulated learning (SRL). The finished components were then integrated into an interactive video platform to ensure everything is well synchronized, including the learning content, visual design, audio narration, and interactive activities. Figures 2 show the interface of the interactive learning video.



Figures 2. The interface of an interactive mathematics learning video

Validity of the interactive mathematics video

After the interactive mathematics learning video was successfully developed, the next step was expert validation. Expert validators were involved to validate the interactive mathematics learning video. The validators included lecturers and teachers. They assessed the media appearance, the language quality, the accuracy of the mathematical concepts, and how well the video supports the self-regulated learning (SRL) indicators. Table 5 presents the results of the video validation.

Table 5. The validity result for the video

Evaluation Aspect	Percentage	Category
Media appearence	80.00	Valid
Quality of language	81.67	Highly Valid
Accuracy of the mathematical concept	85.00	Highly Valid
Average	**82.22**	**Highly Valid**

Table 5 shows that the results of the expert validation indicate that the developed video meets the highly valid aspect. The experts' validation results also show that the average validity score reaches 88.80%, which falls into the highly valid category. Therefore, the learning video is considered valid and appropriate to be tested with students and used as a learning medium in the teaching and learning process according to the experts' assessment.

Practicality of the interactive mathematics video

The practicality test for the use of the video was conducted before the video was implemented in the experimental class. The trial involved 30 students from class X DKV 2. The aspects evaluated in this practicality test included the video's appearance and user comfort, as well as the way it presented the material and supported students' self-regulated learning. Table 6 presents the results of the practicality test calculations for using the video.

Table 6. The practicality result for the video

Evaluation Aspect	Percentage	Category
User appearance and comfort	88.06	Highly Practical
Presentation of the material	89.17	Highly Practical
Supporting independent learning	89.17	Highly Practical

Average	**88.80**	**Highly Practical**

Table 6 shows that the results of the practicality test conducted with students indicate that the developed video meets the **highly practical** category. This is reflected in the aspects of user comfort, the way the material is presented, and how well the video supports students' self-regulated learning (SRL).

Effectiveness of the interactive mathematics video

Before conducting the effectiveness test using MANCOVA, the first step is to test the normality and homogeneity of the data. Table 7 presents the results of the normality test for the data.

Table 7. Normality test result

Aspects	Types of assesment	Class	Saphiro - Wilk		
			Statistic	df	Sig.
Self-Regulated Learning	Pretest	Control	0.961	30	0.333
		Experiment	0.982	30	0.867
	Posttest	Control	0.963	30	0.367
		Experiment	0.981	30	0.846
Mathematical Literacy	Pretest	Control	0.964	30	0.398
		Experiment	0.979	30	0.800
	Posttest	Control	0.964	30	0.387
		Experiment	0.963	30	0.362

Based on the results shown in Table 7, the significance values for both the pretest and posttest data—covering students' mathematical literacy and self-regulated learning—were greater than 0.05. Therefore, it can be concluded that each dataset follows a normal distribution. After the normality test, the next step was to test the homogeneity of the data. Table 8 presents the results of the homogeneity test for the data.

Table 8. Homogeneity test result

Aspects	Types of assesment	Based on Mean	
		Levene Statistic	Sig.
Self-Regulated Learning	Pretest	2.097	0.153
	Posttest	0.002	0.968
Mathematical Literacy	Pretest	2.064	0.156
	Posttest	0.045	0.833

Table 8 shows that the pretest and posttest data related to students' self-regulated learning and mathematical literacy have a significance value greater than 0.05. This indicates that the variances in both groups namely the control class and the experimental class are homogeneous at both the pretest and posttest stages. In the next step, since the data meet the assumptions of normality and homogeneity and also fulfill the requirements for conducting MANCOVA, the analysis will be continued using the MANCOVA test. Table 9 presents the results of the MANCOVA test for the available data.

Table 9. MANCOVA Multivariate test result

Effect		Value	F	Hypothesis df	Error df	Sig
Class	Pillai's Trace	0.950	523.297[b]	2.000	55.000	0.000
	Wilks' Lamda	0.050	523.297[b]	2.000	55.000	0.000
	Hoteling's Trace	19.029	523.297[b]	2.000	55.000	0.000
	Roy's Largest Root	19.029	523.297[b]	2.000	55.000	0.000

Table 9 shows that Wilks' Lambda is 0.050 with a significance value of 0.000 (< 0.05). This indicates a significant simultaneous effect of the treatment applied to the control and experimental classes on students' posttest scores for self-regulated learning and mathematical literacy after controlling for their pretest scores. Next, the partial or univariate interpretation will be explained based on the results in Table 10.

Table 10. Test of Between-Subject Effects

Source	Dependent Variabel	Type III Sum of Square	df	Mean Square	F	Sig
Class	Posttest Score of Self-Regulated Learning	3754.503	1	3754.503	1065.443	0.000
	Posttest Score of Mathematical Literacy	1252.893	1	1252.893	19.879	0.000

The significance value for the posttest scores of self-regulated learning is 0.000 (< 0.05), indicating that there is a significant difference in the effect of the treatment given to the classes on students' posttest self-regulated learning scores. Similarly, the posttest score for mathematical literacy has a significance value of 0.000 (< 0.05), which suggests that the treatment produces a significant difference in students' posttest mathematical literacy scores. Next, a follow-up test will be conducted to determine which treatment is the most influential on the posttest scores. The results of the follow-up test are presented in Table 11, which shows the pairwise comparisons.

Table 11. Pairwise Comparation

Dependent Variable	Class (I)	Class (J)	Mean Difference (I-J)	Std. Error	Sig. [b]	Lower Bound	Upper Bound
Posttest Score of Self-Regulated Learning	Control Class	Experiment Class	-35.721*	1.904	0.000	-37.913	-33.528
	Experiment Class	Control Class	35.721*	1.904	0.000	33.528	37.913
Posttest Score of Mathematical Lteracy	Control Class	Experiment Class	-20.635*	4.628	0.000	-29.906	-11.364
	Experiment Class	Control Class	20.635*	4.628	0.000	11.364	29.906

Based on Table 11, the differences in posttest scores for self-regulated learning have a significance value of 0.000 (< 0.05). Therefore, it can be concluded that there is a significant difference in the effect of the treatment applied to the control and experimental classes on students' posttest self-regulated learning scores. Table 11 also shows that the differences in posttest scores for mathematical literacy have a significance value of 0.000 (< 0.05). Thus, it can be concluded that there is a significant difference in the effect of the treatment applied to the control and experimental classes on students' posttest mathematical literacy scores.

Discussion

The findings of this study demonstrate that the interactive mathematics learning video integrating Canva-AI and deep learning approaches achieved a highly valid category based on expert evaluations. The validation results indicate that the developed learning media successfully aligned instructional objectives, mathematical content, visual presentation, and interactive learning activities within vocational mathematics education. The high validity score also reflects that the learning video possesses strong pedagogical and theoretical foundations appropriate for supporting mathematical literacy and self-regulated learning. The integration of contextual mathematical problems, reflective learning activities, and multimedia visualization contributed positively to the

overall quality of the instructional media. These findings are consistent with previous studies reporting that interactive multimedia learning environments can improve instructional quality by providing more meaningful and visually supported learning experiences (Abdulrahaman et al., 2020; Alpizar et al., 2020; Davis & Frederick, 2020; Noetel et al., 2022). Earlier research also demonstrated that mathematics learning videos integrating contextual visualization and interactive components tend to achieve high validation results because they support conceptual understanding more effectively than conventional instructional media. In addition, studies related to AI-assisted instructional media have emphasized that adaptive and visually attractive learning materials improve content accessibility and instructional relevance for digital-native students (Cheng et al., 2025; Xiong & Bao, 2025). The use of Canva-AI in this study also strengthens the flexibility and attractiveness of the learning videos because multimedia elements can be integrated more systematically and interactively. Compared to previous studies that primarily focused on general multimedia development, this research specifically integrates deep learning principles and vocational mathematics contexts into AI-assisted interactive learning videos. Therefore, the validation findings confirm that the developed learning videos are theoretically and pedagogically appropriate for improving mathematics learning quality in vocational education environments.

The practicality findings further indicate that the developed interactive learning videos were highly practical and well accepted by vocational students during implementation. Students reported that the videos were visually attractive, easy to use, and supportive of independent learning activities. The practicality results suggest that integrating Canva-AI into mathematics learning media can increase students' engagement and learning accessibility by providing flexible and interactive learning experiences. Interactive learning videos allow students to revisit learning materials repeatedly according to their own learning pace and preferences, which supports personalized learning experiences. These findings are aligned with previous studies showing that multimedia-based learning environments can improve students' participation, learning motivation, and classroom engagement (Hidayati & Slamet, 2025; Staneviciene & Žekienė, 2025). Earlier research also reported that interactive instructional videos are effective in reducing students' cognitive burden because information is presented visually and systematically. In vocational education contexts, visual and contextual learning materials are particularly important because vocational students often prefer practical and application-oriented learning experiences. Compared to traditional mathematics instruction that heavily relies on textbooks and teacher explanations, interactive videos provide more dynamic and student-centered learning opportunities. The incorporation of interactive quizzes, contextual examples, and reflective activities in the learning videos also contributed to students' positive perceptions regarding usability and instructional clarity. Therefore, the practicality findings indicate that the developed learning videos are suitable for implementation in vocational mathematics classrooms and can support more engaging learning environments.

The effectiveness analysis revealed that the interactive mathematics learning videos significantly improved students' mathematical literacy and self-regulated learning compared to conventional instruction. The MANCOVA analysis confirmed a significant combined effect of the treatment on students' posttest scores after controlling for pretest performance. These findings indicate that the integration of Canva-AI and deep learning approaches contributes positively to students' conceptual understanding and learning autonomy simultaneously. Students in the experimental group demonstrated better abilities in understanding contextual mathematical problems, applying mathematical reasoning, and interpreting mathematical information. In addition, the improvement in self-regulated learning suggests that students became more capable of planning, monitoring, and evaluating their own learning processes independently. These findings are consistent with previous studies reporting that interactive multimedia learning environments

positively influence mathematical understanding and learning autonomy (Liu et al., 2024; Mohammadi Zenouzagh et al., 2023; Soe et al., 2025). Research related to AI-assisted learning has also emphasized that adaptive multimedia environments support active engagement, reflective learning, and independent learning behaviors more effectively than conventional instructional approaches (Huang, 2025; Meng et al., 2025; Salhab & Aboushi, 2026). Furthermore, previous studies on self-regulated learning have shown that technology-enhanced learning environments encourage students to become more responsible for their learning activities through flexible and autonomous access to instructional materials. Compared to earlier studies that focused primarily on conceptual understanding or academic achievement, this study demonstrates that AI-assisted interactive learning videos can simultaneously improve mathematical literacy and self-regulated learning within vocational mathematics education. Therefore, the effectiveness findings strengthen the argument that integrating interactive multimedia, artificial intelligence, and deep learning approaches can create more meaningful and student-centered mathematics learning experiences.

The improvement in mathematical literacy observed in this study can be explained through the integration of contextual problem-solving activities and meaningful multimedia representations within the learning videos. The videos presented exponential function material through authentic situations connected to vocational and real-life contexts, allowing students to understand mathematical concepts more meaningfully. Contextual learning experiences encourage students to connect abstract mathematical concepts with practical applications, thereby improving conceptual understanding and reasoning abilities. Interactive multimedia elements such as animations, narration, and visual simulations also supported students in understanding complex mathematical relationships more effectively. These findings support multimedia learning theory, which explains that combining verbal and visual information can strengthen students' cognitive processing and conceptual understanding. Previous studies have similarly reported that contextual and multimedia-supported mathematics instruction improves students' mathematical literacy by facilitating active exploration and reflective thinking. In addition, the use of interactive tasks and problem-solving activities encouraged students to engage more actively in mathematical reasoning processes rather than merely memorizing formulas and procedures. The implementation of deep learning approaches also contributed to the improvement of mathematical literacy because students were encouraged to analyze, interpret, and apply mathematical concepts in diverse situations. Compared to conventional teacher-centered instruction, the developed learning videos provided more opportunities for students to construct understanding independently through exploration and reflection. Therefore, the improvement in mathematical literacy indicates that integrating contextual learning, multimedia visualization, and deep learning principles can strengthen students' higher-order mathematical thinking skills.

The improvement in self-regulated learning identified in this study reflects the important role of interactive and AI-assisted learning environments in promoting students' autonomy and independent learning behaviors. The learning videos provided students with opportunities to learn flexibly, revisit instructional materials independently, and monitor their own learning progress throughout the learning process. Reflective learning activities integrated into the videos also encouraged students to evaluate their understanding and identify learning difficulties more actively. These findings are consistent with self-regulated learning theory, which emphasizes the importance of goal setting, self-monitoring, reflection, and independent strategy use in successful learning processes. Previous studies have similarly shown that technology-enhanced learning environments can strengthen students' learning autonomy by providing greater control over learning activities and learning pace. AI-assisted multimedia learning also supports self-regulated learning because students can access instructional materials repeatedly and receive immediate feedback during the learning process. In vocational education, self-regulated learning is particularly important because

vocational students are expected to become adaptive learners capable of responding to workplace challenges and technological changes. Compared to conventional learning environments where students are often passive recipients of information, the developed learning videos encouraged active engagement, independent exploration, and reflective learning behaviors. The large effect size observed in self-regulated learning further indicates that the integration of Canva-AI and deep learning approaches successfully created learning environments that support student autonomy and meaningful learning participation. Overall, this study demonstrates that AI-assisted interactive mathematics videos can serve as an effective instructional innovation for improving both mathematical literacy and self-regulated learning in vocational mathematics education.

Implications

The findings of this study provide important theoretical and practical implications for the development of mathematics education in vocational learning environments. The successful integration of Canva-AI and deep learning approaches into interactive mathematics videos demonstrates that artificial intelligence-assisted multimedia can effectively support meaningful and student-centered learning experiences. The study also strengthens the theoretical perspective that contextual and technology-enhanced learning environments contribute positively to the development of mathematical literacy and self-regulated learning simultaneously. From a pedagogical perspective, the findings suggest that mathematics instruction should move beyond conventional teacher-centered approaches toward more interactive, reflective, and contextual learning models. The use of interactive learning videos allows students to engage actively with mathematical concepts through visual representation, contextual problem solving, and independent exploration activities. In vocational education contexts, this instructional innovation is particularly relevant because vocational students require flexible and application-oriented learning experiences connected to workplace situations and technological developments. The findings further imply that integrating artificial intelligence into instructional media can increase students' engagement, learning accessibility, and autonomy by providing adaptive and visually attractive learning materials. For teachers, the developed learning videos can serve as an alternative instructional medium that supports differentiated instruction and independent learning both inside and outside the classroom. Educational institutions may also utilize AI-assisted interactive learning media to support digital transformation initiatives and improve the quality of technology-enhanced learning environments. In addition, the study highlights the importance of combining deep learning principles with multimedia technology to promote higher-order thinking skills, reflective learning, and conceptual understanding in mathematics education. The results also contribute to the growing discourse regarding the implementation of artificial intelligence in vocational education, particularly in mathematics learning contexts that emphasize student participation and learning autonomy. Therefore, this study provides a foundation for future instructional innovation aimed at developing adaptive, contextual, and sustainable mathematics learning environments in the digital era.

Limitations and Suggestions for Future Research

This study has several limitations that should be considered when interpreting the findings and developing future research. First, the study was conducted within a relatively small sample involving students from a single vocational high school, which may limit the generalizability of the findings to broader educational contexts. Second, the research focused only on exponential function material, so the effectiveness of the interactive learning videos on other mathematical topics remains unexplored. Third, the duration of the implementation was relatively short, meaning that the long-term effects of the learning videos on students' mathematical literacy and self-regulated learning could not be comprehensively examined. Fourth, the study primarily emphasized quantitative outcomes, while deeper qualitative exploration regarding students' learning experiences,

perceptions, and challenges during the implementation process was limited. In addition, differences in students' technological familiarity and digital literacy levels may have influenced their engagement with the AI-assisted learning media. The study also did not extensively investigate external variables such as learning motivation, classroom climate, teacher facilitation styles, and family learning support that could potentially affect students' mathematical literacy and self-regulated learning outcomes. Furthermore, the implementation of Canva-AI was still limited to interactive multimedia integration and did not involve more advanced adaptive AI features such as personalized learning analytics or intelligent feedback systems. Future studies are therefore recommended to involve larger and more diverse samples from multiple educational institutions and vocational programs to improve the generalizability of the findings. Further research should also examine the implementation of AI-assisted interactive learning videos across different mathematical topics and educational levels to identify broader instructional impacts. Longitudinal studies are additionally needed to investigate the sustainability of improvements in mathematical literacy and self-regulated learning over extended learning periods. Future researchers are also encouraged to integrate qualitative approaches such as interviews, reflective journals, and classroom observations to gain deeper insights into students' learning experiences and engagement with AI-assisted instructional media. Finally, future instructional development should consider integrating more adaptive artificial intelligence features, collaborative learning environments, and personalized feedback systems to strengthen student-centered mathematics learning in vocational education contexts.

CONCLUSION

This study concludes that the integration of Canva-AI and deep learning approaches into interactive mathematics learning videos provides a valid, practical, and effective instructional innovation for vocational mathematics education. The developed learning videos successfully fulfilled the criteria of instructional validity through the alignment of mathematical content, visual presentation, contextual learning activities, and deep learning principles. The practicality findings also indicate that the interactive learning videos were well accepted by students because they were visually attractive, easy to use, and supportive of independent learning activities. Furthermore, the implementation of the interactive videos significantly improved students' mathematical literacy and self-regulated learning compared to conventional instructional approaches. The improvement in mathematical literacy demonstrates that contextual problem-solving activities and multimedia representations can support students' conceptual understanding and mathematical reasoning more effectively. At the same time, the increase in self-regulated learning indicates that AI-assisted interactive learning environments can encourage students to become more autonomous, reflective, and responsible for their own learning processes. The integration of Canva-AI also contributed to creating more adaptive, flexible, and engaging learning experiences suitable for vocational students' characteristics and learning needs. In addition, the implementation of deep learning principles supported meaningful learning experiences by encouraging active participation, contextual understanding, and reflective thinking during mathematics learning activities. The findings of this study further strengthen the perspective that technology-enhanced learning environments can improve both cognitive and non-cognitive learning outcomes simultaneously. This research also contributes theoretically to the growing discussion regarding the integration of artificial intelligence, interactive multimedia, and deep learning approaches in mathematics education. From a practical perspective, the developed learning videos may serve as an alternative instructional medium that supports student-centered and technology-enhanced learning in vocational education settings. Overall, this study highlights the potential of AI-assisted interactive mathematics videos to support

the development of meaningful, contextual, and autonomous learning environments relevant to educational transformation in the digital era.

AUTHOR CONTRIBUTIONS STATEMENT

Yolanda Pratiwi was responsible for the research conceptualization, development of the interactive mathematics learning videos integrating Canva-AI and deep learning approaches, data collection, implementation of the instructional treatment in vocational classrooms, statistical data analysis, and manuscript drafting. Fitrianto Eko Subekti contributed to the research supervision, methodological validation, instructional media evaluation, interpretation of the research findings, and critical revision of the manuscript. Both authors participated in the development of the theoretical framework, validation of the research instruments, refinement of the instructional design, and final manuscript review. All authors were actively involved in discussing the findings, approved the final version of the manuscript, and agreed to be accountable for all aspects of the research.

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