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STEM-Based Parabolic Motion Learning: AI-Assisted Video Development for High School Students

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Abstract

STEM learning is increasingly relevant in facing the challenges of 21st-century education. The use of technology, including artificial intelligence (AI), is expected to improve the effectiveness of the teaching and learning process. This study develops AI-supported STEM learning videos on parabolic motion for 11th-grade high school students. The methodology used follows the Alessi and Trollip model, which includes the stages of planning, design, expert validation, and practical testing. The methodology used follows the Alessi and Trollip model, which includes the stages of planning, design, expert validation, and practical testing. Initial practical testing scored 95%, and follow-up testing scored 94%. The N-gain value reached 0.57, categorized as effective. The findings indicate that the video is suitable for use in the learning process and is capable of improving students' understanding of abstract concepts and motivating them. This study emphasizes the importance of integrating AI and STEM in the development of innovative learning media.

Keywords: video learning, artificial intelligence, parabolic motion, STEM

INTRODUCTION

Reforms in education occur as a result of technological advances. These changes have a significant impact on education, including the curriculum. The Independent Curriculum is a curriculum that employs varied learning approaches, where subject matter is optimized so that students have sufficient time to strengthen their abilities and explore concepts (Wahidin, Sarbini, & Tabroni, 2022). This freedom serves as an encouragement for students to explore knowledge and develop independent character (Vhalery, Setyastanto, & Leksono, 2022). The implementation of the Independent Curriculum provides a quality learning process, in which the teacher's role goes beyond merely delivering information (Suhandi & Robi'ah, 2022). Currently, the Independent Curriculum is launched as an effort to create a quality educational climate, enabling educators and students to adapt to ongoing technological transformations (Arisanti, 2022).

Technology alone is not sufficient to serve as the main tool for mastering 21st-century skills, educators must also pay attention to factors that support these skills. The three main categories of 21st-century skills include media and technology, learning and innovation, and life and work skills (Herawati, Aminarti, & Rosdiana, 2023). These skills are relevant to the challenges of the 21st century, such as critical thinking, innovation, collaboration, communication, and a deep understanding of global issues (Lubis et al., 2023). Therefore, relevant learning approaches are needed to support the rapid development of technology, which contributes to improving the quality of education through STEM learning.

STEM is a learning approach that integrates the application of science and technology through engineering based on mathematical elements (Ramiawati & Yunus, 2021). STEM learning directs students to think critically (critical thinking), work well (collaboration), communicate (communication), creativity (creativity) to solve problems that occur in everyday life (Nurhaifa, Hamdu and Suryana, 2020). explain learning attitudes as fun learning people who enjoy using STEM curriculum integrated with multimedia videos will actively study STEM or look for STEM-related information (Shiau et al, 2020). This will strengthen students' self-learning attitude and cultivate the habit of thinking. Conventional learning is no longer favored by students especially in science, therefore teachers need to update information to enrich teaching content relevant to technological developments (Yi Meng, 2023). In addition, the use of STEM- based mobile learning is expected to provide real and concrete examples of STEM learning in the classroom supported by enrichment modules, lesson plans, media, student worksheets, test questions and performance assessments (Firdaus and Hamdu, 2020). Student responses were very enthusiastic in using this learning video. One way to utilize technology to provide convenience for students in the learning process is through learning media.

Media in the learning process today must be associated with technological sophistication (Cloonan and Fingeret, 2020). Learning media is an intermediary tool to convey material to students so that it is easier to understand (Wulandari et al., 2023). Learning multimedia plays an important role in the success of the learning process. One form of multimedia is video which can increase understanding, improve learning outcomes and has great potential to facilitate learning (Desai and Kulkarni, 2022). The assignments given to them in the form of homework are not equipped with a process to understand the material taught. The availability of learning media is also still minimal, especially those consisting of essential resources (Markos Siahaan et al., 2023). One example of learning media that can be applied is video.

The effective combination of digital technology multimedia technology and artificial intelligence (AI) has been widely used in various fields. The benefits of integrating artificial intelligence (AI) in open and distance learning can revolutionize education by improving efficiency, personalization, and assisting the student learning process (Liu, 2022). The integration of AI in education has shown promising results in improving the quality of the teaching and learning process, increasing student engagement, and personalizing the learning experience. Generative AI technology can be used to create innovative and engaging educational content, such as interactive learning modules, animated videos, or learning materials tailored to individual student needs (Mhlanga, 2023; Baidoo and Owasunah, 2023).

Technology integration, such as AI-assisted video production, has revolutionized video development that generates 3D character animations automatically from videos using artificial intelligence (Holzinger et al., 2019). Through extracting image information to generate appropriate 3D character animations based on the given information and provide a more attractive animation appearance (Xian and Sahagun, 2023; Weng, Curless and Kemelmacher-Shlizerman, 2019). This helps animators to perform work in an easy way and frees animators from repetitive work (Liu, 2022). In the context of teaching high school students about parabolic motion, the development of AI-validated learning videos can be a powerful tool to improve critical thinking skills. The effectiveness of teaching AI fundamentals to high school students has been demonstrated, highlighting the potential of interactive workshops covering topics such as building unbiased data sets and interpretable classifiers (Luo and Yang, 2022). Similarly, the emergence of Generative AI has been identified as a cornerstone technology in education, with the ability to personalize learning experiences and provide high-quality feedback to students (Mello et al., 2023). However, humans use AI only as a tool to help make tasks easier and more automated. AI is and will continue to be good at automated tasks but not creative ones (Chatterjee, 2022). Therefore, AI can be utilized by educators as a tool to develop videos or learning media tailored to learning objectives.

Based on the results of interviews and observations of researchers with class XI physics teachers in high school that the facilities and infrastructure available at school can support overall learning activities at school, especially in physics subjects teachers only use conventional models. The condition of the students also in understanding physics is still lacking and feel that physics is rather difficult to understand and their enthusiasm in learning decreases slightly and results in the value of the exam results after averaging specifically for physics subjects is low and has not met the minimum completeness criteria.

Based on the background presented, the researcher intends to conduct a study on STEM- AI-based learning videos to train high school students' critical thinking skills related to kinematics specifically parabolic motion sub-materials. The STEM approach was chosen so that the learning media can be applied properly. The purpose of this study is to determine the feasibility of STEM-AI-based learning videos to train high school students' critical thinking skills related to special kinematics. parabolic motion sub-material can be used as a supporting media in the teaching and learning process.

METHODS

The method used in this research is development research (R&D), which is designed to create certain products and assess the effectiveness of the methods applied (Azzahra, Nurhasanah and Utami, 2022). This research aims to develop STEM-AI-based learning media. The model used in this development is the Alessi and Trollip model, which focuses on developing videos supported by artificial intelligence technology. The development research procedure is illustrated in FIGURE 1.

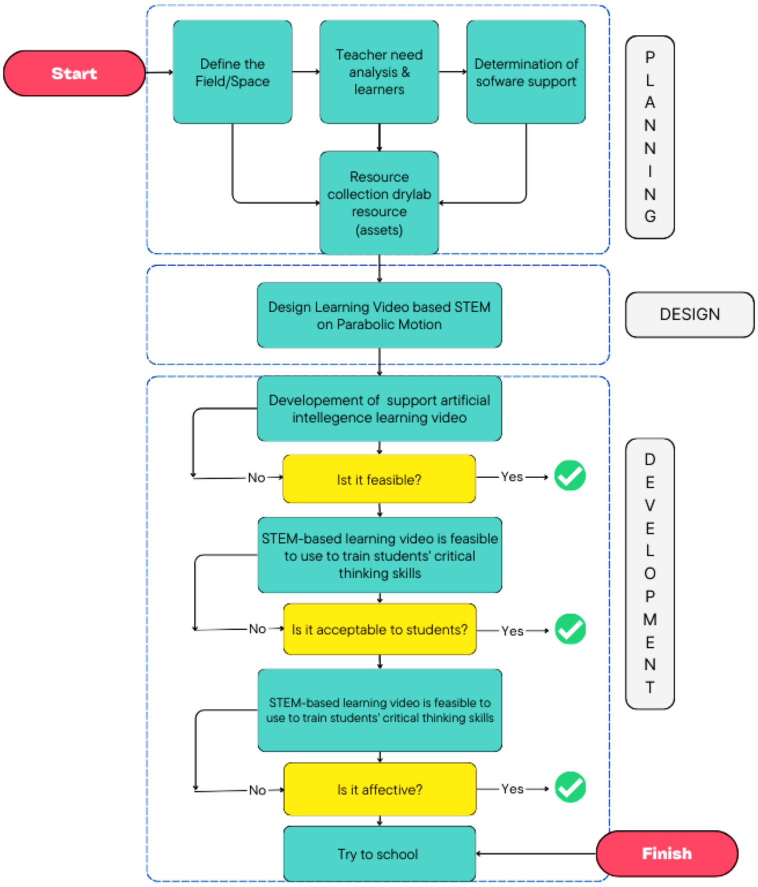

FIGURE 1. Alessi & Trolip model procedure

The Alesi and Trolip development model begins at the planning stage which includes analyzing learning needs, then determining learning objectives and designing learning videos, as well as developing learning videos involving material experts, learning design experts, and learning media experts as validators. This development was carried out with the target users being high school students. The selection of material experts is based on the competence of expert subjects, namely lecturers.

The next stage is design. This stage consists of seven sub-components, namely: a) developing content ideas, b) conducting task and concept analysis, c) conducting initial program descriptions, d) preparing prototypes, e) creating flowcharts and storyboards, f) preparing scripts, and g) getting approval from clinicians. One of the activities in this design stage is to carry out task and concept analysis. The result of this design stage is a flowchart that will determine the sequence of material, develop a storyboard, and determine the supporting sources (script, video, audio, etc.) needed.

The development stage is the pouring of design concepts into a mature product. The sub-components in this development stage consist of two sub-components, namely: a) preparing text, b) writing program code, c) creating graphics, d) producing audio & video, e) assembling the work, f) preparing supporting materials, g) conducting alpha tests, h) making revisions, i) conducting beta tests, j) making final revisions, k) getting client signatures, and l) validating the program.

Population and Sample

This study focused on the population of 11th-grade students at Senior High School 22 Palembang, South Sumatra province. For sampling, cluster random sampling method was used, involving three students. The total sample size used in this study was fiveteen students, who were engaged to try out the STEM-based learning video supported by artificial intelligence.

Instrument

Gathering research information through qualitative analysis involves using various instruments at each stage of the research. Each stage required different instruments, including the development of a questionnaire containing a list of questions for observation. The instrument development and validation process was conducted by experts using a questionnaire of Guttman scaled instruments, as shown in TABLE 1. Research data were collected through video validation with validation sheets prepared by educational experts and practitioners in the field. Validation analysis was conducted by applying a Guttman scale consisting of 0 (No) and 1 (Yes). The validators involved in validating the artificial intelligence video included material content expert validators, media expert validators, and material productivity and innovation validators.

TABLE 1. Expert Validation Instrument

Aspect	Statement	Item Number
Content/Material	Coverage of the material	1, 2, 3
	Alignment of material with Learning Outcomes (LO) and Learning Objectives	4, 5, 6, 7, 8
	Use of correct Indonesian language rules	4, 5, 6, 7, 8
	Suitability of the STEM approach and accuracy of material	8, 9
	Appropriateness of critical thinking indicators	10
Media Display	Structured presentation of material	11, 12
	Quality of text, images, and audio	13, 14, 15, 16, 17
Usefulness	Coverage of innovation and productivity of the material	18, 19, 20

TABLE 2 shows the Student Response Questionnaire Instrument, including the indicators and items used to assess students' responses toward the implemented learning video.

TABLE 2. Student Response Questionnaire Instrument

Aspect	Statement	Item Number
Content and Presentation of Material	Ease of use	1, 2, 3
	Components in the presentation	4, 5, 6, 7, 8, 9
	Usefulness	10, 11, 12

Data Analysis

The data analysis process is carried out to process the information obtained during the evaluation by utilizing the predetermined instruments. In this study, the data analysis applied was alpha test analysis to assess feasibility, based on the evaluation proposed by Alessi and Trollip, with the answer categories divided into acceptable and requires improvement (Allesi and Trollip, 2001). The categories set by Trollip include acceptable answers as well as those that require improvement. The feasibility of the research method used, namely Alessi and Trollip, will be achieved if all aspects of the instrument reach 100%. These aspects are indicates that the validation instrument is acceptable. If there are aspects that require improvement, then these aspects will be improved until they are declared feasible by the relevant experts. The stages of data analysis carried out include validity tests (as shown in TABLE 3) and practicality tests (as shown TABLE 4).

TABLE 3. The interpretation of the content validity category

Validations (%)	Category
0-20	Invalid
21-40	Not Valid
41-60	Quite valid
61-80	Valid
81-100	Very valid

TABLE 4. The interpretation of the practicality score

Practicality (%)	Interpretation
0 - 20	Not practical
21 – 40	Less practical
41 – 60	Practical enough
61 – 80	Practical
81 - 100	Very practical

The effectiveness of the learning implementation was analyzed using the N-Gain score and the classification results are shown in TABLE 5.

TABLE 5. Effectiveness category based on N-Gain

N-gain Value	Criteria	Effectiveness Category
N-gain ≥ 0.7	High	Very Effective
0.7 > N-gain ≥ 0.3	Medium	Effective
N-gain < 0.3	Low	Less Effective

The data analysis stage carried out is the validity test and the practicality test. Data analysis in this study in detail is presented in TABLE 6.

TABLE 6. Specified data variables, instruments and data analysis

Variables	Required data	Instrument	Data Analysis
Validity	Content aspect validation, context and productivity	Validation sheet content, context, and media productivity	Descriptive statistics, percentage technique
Practicality	Student Response	Questionnaire	Descriptive statistics and percentage technique.

RESULTS AND DISCUSSION

Result

Planning

The initial process was to identify the needs. The needs were taken from one of the schools in Palembang city which has adequate facilities. Observation shows that the learning media used is more often in the form of printed media and videos from YouTube. The cause is the lack of teacher creativity in utilizing learning media. With the development of increasingly advanced technology, teachers should be able to explore various learning media that are more interesting.

Design

In this phase, the integration of material content and learning media design is carried out to create a prototype learning video. Science concepts were analyzed and developed into video content. The results showed that the selected material covered 11th-grade with parabolic motion as the subject. Initial observations at one of the high schools in Palembang indicated that students need a deeper understanding in learning physics, so they have not been able to identify the process of parabolic motion. This finding is also supported by previous research which shows that several factors contribute to low student understanding, one of which is the tendency to solve memorized problems without a deep understanding of the content physics. The next step is to create a flowchart. Flowchart is a visual representation of a sequence of steps or processes in the form of graphical symbols. Flowchart helps in visualizing the workflow or procedure of the media product developed, as shown FIGURE 2.

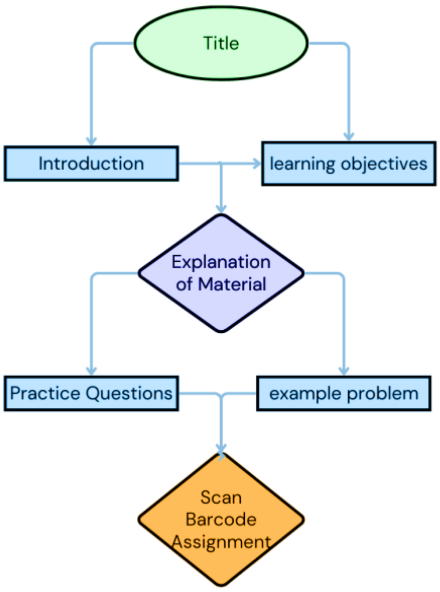

FIGURE 2. Flowchart development of video

The next process is to create a learning video supported by artificial intelligence, which has been designed based on the video script or storyline. The process of making learning videos is done using the Canva application, while character animation is made using the AI application, D-DI Presenters. Then for the background size used is 2048 x 1440 pixels with an aspect ratio of 16:9. After all the supporting elements are prepared, then design the learning video in the canva application.

Development Stage

The development process began with the preparation of the text to be used in the media, followed by the creation of graphic design using a combination of artificial intelligence and Canva applications. In addition, integrating sound and video elements into the media can increase student attraction and attention, as well as bringing together the various elements that have been created to assess harmony in the preparation of learning videos. At this stage, additional materials are also prepared. The initial trial will involve expert validators who will provide assessments, comments and suggestions to ensure the validity of the learning media produced. Furthermore, revisions will be made based on evaluations from expert validators, followed by trials involving students to assess the level of practicality of the learning video media that has been developed. The development results on parabolic motion material can be seen in FIGURE 3 and FIGURE 4.

FIGURE 3. Initial View of the learning video

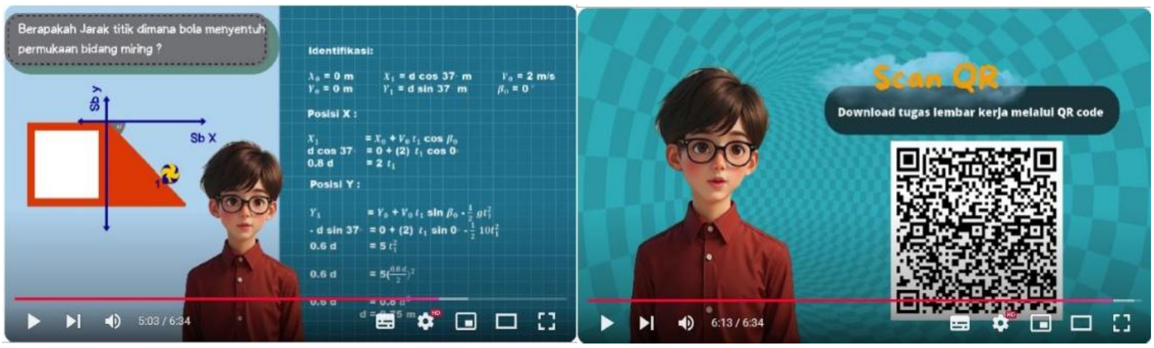

FIGURE 4. Interaction contained in the video

After the completion of the learning video prototype focusing on parabolic motion material, the researchers conducted validation with experts. The validated aspects in this media include content (parabolic motion), language used, and learning media design. The following are the results of the assessment of each expert validator of the video AI-assisted learning. In the next step, researchers improved the AI-assisted STEM-based learning video that had been produced through validation of material content, media, and productivity and innovation. In the validation phase, the learning video integrating STEM-AI was evaluated by seven expert educational practitioners to assess its feasibility. The following is an explanation of the results of the validation phase.

Material Content and Media Expert Validation

During the validation phase, the educational video was assessed for its suitability by five experts who evaluated it based on content and media aspects. This educational video is divided into three segments, each with a maximum duration of seven minutes. The video includes animations that explain parabolic motion, incorporates STEM elements, and features 3D animations to illustrate the concept of parabolic motion, along with a QR code for student activity tasks. The findings of the research are presented in a table detailing the validity results from media and content experts regarding the STEM-based educational video supported by AI in TABLE 7 and TABLE 8.

TABLE 7. Material or content expert validation results

Validators	score	scoremax	percentage	category
Expert 1	12	12	100%	Very Valid
Expert 2	12	12	100%	Very Valid
Expert 3	10	12	83.3%	Very Valid
Expert 4	12	12	100%	Very Valid
Expert 5	10	12	83.3%	Very Valid

The validation conducted by content experts resulted in a percentage of 93.32%, which falls within the category of highly valid. As per the criteria established in the expert validation table, a score between 81-100% signifies that the media is considered highly valid for application.

TABLE 8. Media expert validation result

Validators	score	scoremax	percentage	category
Expert 1	6	7	85.7%	Very Valid
Expert 2	7	7	100%	Very Valid
Expert 3	7	7	100%	Very Valid
Expert 4	7	7	100%	Very Valid
Expert 5	6	7	85.7%	Very Valid

The validation results from media experts yielded a percentage score of 94.28%, categorizing the media as highly valid. According to the validation criteria outlined in the expert validation table, a score ranging from 81% to 100% indicates that the media is deemed highly valid for use.

Practicality of the Learning Video

The practicality of this learning video is measured through students' responses to the video used in teaching parabolic motion material. Student responses regarding the use of the learning video can be seen in FIGURE 5.

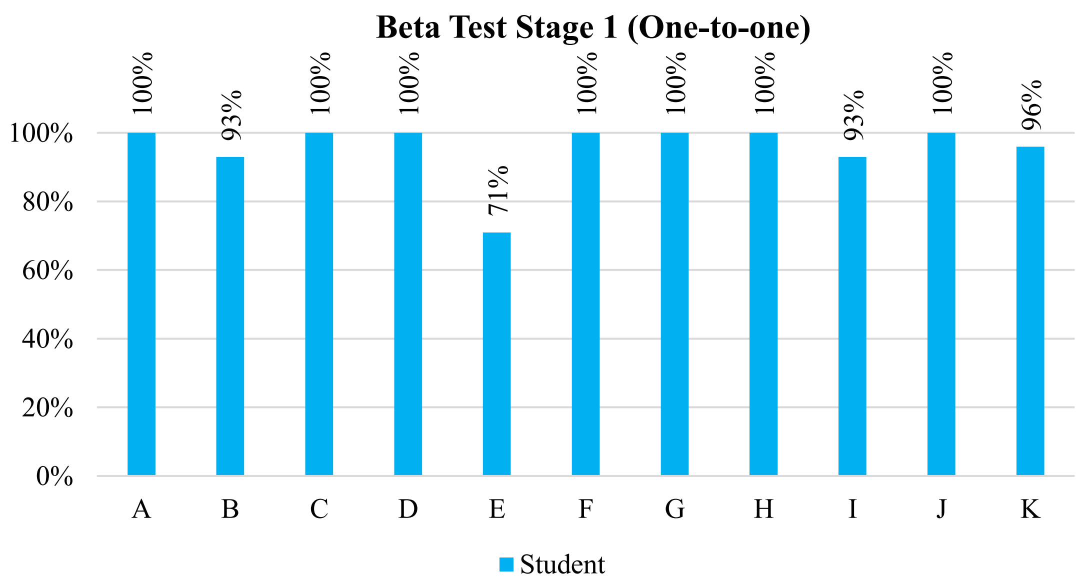

FIGURE 5. Results of Beta Test 1 Learner responses

FIGURE 5 indicates that students showed a high level of agreement with the use of learning videos as an alternative media in physics learning at the beta test stage 1. From the results of the initial trial of the STEM-based learning video supported by AI, 95% of students gave positive responses in the questionnaire, which indicates that the percentage is classified as "very practical". The beta 1 trial involving ten students was conducted to evaluate the practicality on a small scale. Therefore, minor improvements were made to the learning video before proceeding to the small group stage (beta 2 test) to explore more diverse student assessments.

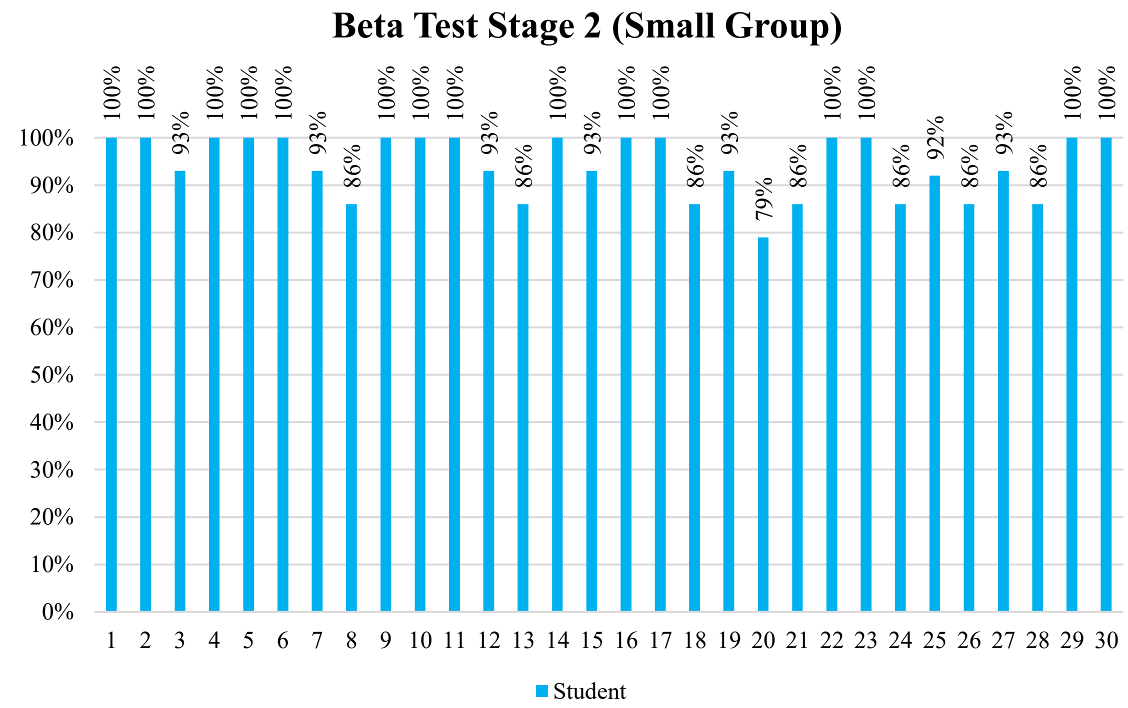

FIGURE 6. Beta test learner responses 2

Based on FIGURE 6, it illustrates that students at the beta 2 test stage showed a high level of approval for the use of STEM-based learning videos supported by AI in parabolic motion material. From the results of the beta 2 trial involving 30 students, 94% was obtained, which indicates that the percentage is considered "very practical". This finding indicates that the learning media can increase the attractiveness for students.

Effectiveness Test Results

The effectiveness test calculation process was obtained by calculating the N-Gain score based on the students' pre-test and post-test scores related to critical thinking skills. The results of the student effectiveness test are listed in TABLE 9.

TABLE 9. Assessment of Student Learning Outcomes

Class	Student's	Analysis of student learning outcomes		
		Pretest	Posttest	N-Gain
X	30	32.83	71.44	0.57

TABLE 9 shows the results of the analysis of student learning with the application of STEM-AI-based learning videos on the topic of parabolic motion. This test was taken by thirty 11th-grade students, who obtained an average pre-test score of 32.83. After the application of learning using these videos, the average post-test score of students increased to 71.44 with an N-gain of 0.57, which is classified as moderate.

Discussion

The Use of Technology in STEM and AI Learning

The use of technology, particularly Artificial Intelligence (AI), in STEM learning is growing and has great potential to improve the effectiveness of the teaching and learning process. AI is capable of providing interactive and adaptive learning media according to student needs, which can increase their motivation and learning outcomes (Seo et al., 2020)The development of AI-based learning videos, as done in this study, also supports the creation of a more engaging and enjoyable learning experience, thereby overcoming student boredom with conventional methods (Wulandari et al., 2023).

Advantages of Video and AI-Based Learning Media

Video-based learning media supported by AI has advantages in improving concept understanding, especially in understanding abstract material such as parabolic motion. Several previous studies have shown that the use of videos has a number of advantages that have been proven through various studies, one of which is an increase in problem-solving skills among students (Ayuni, Pasaribu and Kumalasari, 2024). Another study revealed that STEM-based learning videos on the topics of waves and sound can improve learning outcomes and student interest (Devi and Subali, 2021). In addition, in situations where face-to-face learning is not possible, other studies show that videos can be combined with virtual experiments, making the learning process more effective (Flegr, Kuhn and Scheiter, 2023).

The Influence of Digital Learning Media on Critical Thinking Skills

This study shows that the use of AI-based STEM videos can improve students' critical thinking skills, which are important competencies in 21st-century education. Through interactive simulations and visualizations, students are encouraged to analyze and solve problems independently, thereby developing critical and creative thinking skills (Lubis et al., 2023). In line with this, the development of innovative learning media throughout the learning process can foster a greater desire to learn and significantly improve learning outcomes (Ayuni, Pasaribu and Kumalasari, 2024).

Feasibility and Effectiveness of AI-Based Learning Media

Validation and field test results show that the AI-based STEM video media developed has a high level of feasibility and safety, and can be used practically in the context of learning in high schools. Its success is supported by the validity of the material, visual appeal, and ease of use, which can increase student active participation in the learning process. This shows that the integration of AI in learning media is not only relevant but also effective as an innovation for future education.

Challenges and Obstacles in Implementing New Technology

Despite its many advantages, the application of AI-based media also faces challenges, such as limited facilities and infrastructure in schools and a lack of creativity among teachers in integrating technology into learning. In addition, regarding the use of technology as a learning medium, the number of teachers who are able to create animated videos is still very limited. This shows that the development and use of learning videos by teachers is not yet optimal. One of the contributing factors is the lack of teachers' ability to utilize artificial intelligence-based technology. In addition, there are many challenges faced in the teaching and learning process through videos. For educators, the process of creating effective learning videos requires considerable time and effort. On the other hand, for students, watching videos is often a less active learning activity (Seo et al., 2020). Therefore, one of the benefits of using animated videos is that they can reduce the workload of teachers and serve as a tool to assist in delivering science material. This also helps students understand the material better (Dewayanti, Sri

Suryanti and Wicaksono, 2023). In addition, teachers can utilize the role of AI to support the creation of varied digital video content, which can help achieve learning objectives in the classroom (Orak & Turan, 2024). The involvement of artificial intelligence will make it easier for students to understand lessons and increase interaction between students and educators (Rahadiantino, 2022).

The Impact of Digital Media Use on Learning Outcomes

This study also confirms that the use of AI-based digital media can improve student learning outcomes and motivation, especially in materials that require visualization of real concepts such as parabolic motion. This is in line with previous research findings that visual and interactive media can significantly improve students' understanding and analytical skills (Herawati, Aminarti and Rosdiana, 2023) Thus, the development of innovative technology-based learning media not only supports the learning process but also improves the overall quality of educational output.

This study also proposes solutions that can be offered if adequate learning media are needed to support students. Several teachers stated that instructional videos are one effective solution. This is in line with the opinion (Ds et al., 2020) that suggests instructional videos be made in short durations so that students can watch the entire video more easily by dividing longer videos into several shorter parts. From the results of a survey of students, almost all students preferred videos with shorter durations to longer ones, because they were considered more interesting and not boring. With the rapid development of media today, there is a view that animated videos are a fast and effective learning tool (Brown et al., 2020; Doheny et al., 2023) and can enhance interdisciplinary learning in education. However, this study still has limitations in the implementation of each stage, so further research is needed to evaluate the effectiveness of STEM-AI-based learning videos in training students' critical thinking skills.

CONCLUSION

Based on the results of the study, it can be concluded that the AI-supported STEM-based learning videos developed for parabolic motion material are highly valid and effective for classroom use. The development process following the Alessi and Trollip model resulted in learning videos that achieved a 100% acceptance rate from expert reviews, indicating their suitability for implementation. Furthermore, the videos effectively enhanced students' critical thinking skills, as reflected by an N-gain score of 0.57, which falls within the effective category. Overall, the integration of AI and STEM in the learning video not only supports conceptual understanding of parabolic motion but also demonstrates the potential of technology-based learning media skills in 21st-century education.

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