Jurnal Pendidikan Indonesia
Volume 13, Number 3, 2024 pp. 415-425
P-ISSN: 2303-288X E-ISSN: 2541-7207
Open Access: https://doi.org/10.23887/jpiundiksha.v13i3.74226

STEM-Based Animation Learning Videos to Improve Critical Thinking Skills and Self-Directed Learning

Siti Wulandari Mamonto[1*], Zuhdan Kun Prasetyo[2], Ujang Sugara[3], Susan N H Jacobus[4]

[1,2,3] Fakultas Ilmu Pendidikan dan Psikologi, Univesitas Negeri Yogyakarta, Yogyakarta, Indonesia
[4] Fakultas Ilmu Pendidikan, Universitas Manado, Manado, Indonesia

ARTICLE INFO

Article history:
Received January 14, 2024
Accepted July 29, 2024
Available online September 25, 2024

Kata Kunci:
Video pembelajaran animasi, Ipa, stem, Gaya belajar, Berfikir kritis, Kemandirian belajar

Keywords:
Animation learning videos, Science, stem, Learning styles, Critical thinking, Independent learning.

ABSTRAK

Penelitian ini dilatarbelakangi oleh rendahnya kemampuan berpikir kritis dan kemandirian belajar siswa sekolah dasar. Penelitian ini bertujuan untuk mengembangkan video pembelajaran animasi berbasis STEM yang layak, praktis, dan efektif dalam meningkatkan dua aspek tersebut. Penelitian menggunakan metode research and development (R&D) dengan model pengembangan 4D yang terdiri dari tahap pendefinisian (define), perancangan (design), pengembangan (develop), dan diseminasi (disseminate) sesuai dengan model Thiagarajan. Subjek penelitian ini melibatkan siswa sekolah dasar sebagai pengguna utama. Pengumpulan data dilakukan melalui uji kelayakan, kepraktisan, dan keefektifan dengan melibatkan ahli materi, ahli media, guru, dan siswa. Analisis data menggunakan uji t independent dan MANOVA untuk keefektifan. Hasil penelitian menunjukkan bahwa video pembelajaran yang dikembangkan dinilai layak oleh ahli materi (91,7) dan ahli media (80). Keefektifan produk terlihat dari hasil uji t independent dan MANOVA dengan signifikansi 0,000. Kepraktisan video dinilai tinggi oleh guru (88) dan siswa (92,8), dengan tingkat keterlaksanaan 100%. Simpulan dari penelitian ini adalah bahwa video pembelajaran animasi berbasis STEM mampu meningkatkan kemampuan berpikir kritis dan kemandirian belajar siswa sekolah dasar secara signifikan, sehingga dapat diimplikasikan dalam pembelajaran.

ABSTRACT

This research is motivated by the low critical thinking ability and learning independence of elementary school students. This research aims to develop STEM-based animation learning videos that are feasible, practical, and effective in improving these two aspects. The research uses a research and development (R&D) method with a 4D development model consisting of the stages of define, design, develop, and disseminate according to the Thiagarajan model. The subject of this study involves elementary school students as the main users. Data collection is carried out through feasibility tests, practicality, and effectiveness by involving material experts, media experts, teachers, and students. Data analysis uses independent t test and MANOVA for effectiveness. The results of the study showed that the learning videos developed were considered feasible by material experts (91.7) and media experts (80). The effectiveness of the product can be seen from the results of the independent t test and MANOVA with a significance of 0.000. The practicality of the video was rated high by teachers (88) and students (92.8), with a 100% implementation rate. The conclusion of this study is that STEM-based animation learning videos are able to significantly improve the critical thinking ability and learning independence of elementary school students, so that it can be implicated in learning.

1. INTRODUCTION

Learning media have various types, such as PowerPoint, videos, and props or items found in the school environment. One of the media mentioned earlier is video learning The fact is that video is a collaboration that is able to produce the rhythm of motion in images and sound. Video can be a means that is able to provide an interesting nuance for students in learning. Learning videos become a useful tool in delivering learning materials (Brame, 2016; Fyfield et al., 2019). Videos can also be actualized into

*Corresponding author
E-mail addresses: wulandari@gmail.com (Siti Wulandari Mamonto)

animations that make it easier to absorb information by students because they have real dimensions so that they can attract students' interest in watching learning videos. In its use, the content contained in the video will be able to convey new knowledge and be able to provide the ability to hone students' skills (Belt & Lowenthal, 2021; Sablić et al., 2021). In order for the message in the learning video to be received properly, a teacher needs to pay attention to the components that must be in the learning video. Components that must be considered are video must be able to manipulate images so that the message to be conveyed can be received properly, objects can be stored in unlimited time, video is able to attract students' attention in watching more than 30 minutes, video must be able to present new, real, happening knowledge and be able to be analogous using reason by students (Heitink et al., 2016; Hughes et al., 2020). It will remain a fact in the field that the use of media still cannot be accommodated and has not involved interactive activities in the classroom for school students. In observations in 5 elementary schools on thematic learning with science content in grade V that implemented the 2013 curriculum, it was found that there was still a lack of interactive learning media based on STEM. In addition, the level of critical thinking skills and learning independence is still below standard. This can be seen in SDN Bhayangkara, SDN Baciro, and SDN Kliteren, in these schools it was found that the PTS (Midterm Assessment) score was still below KKM. The KKM used in the school is 73 in elementary science lessons, but the average student is only 49.34%. This result is supported by PISA 2018 data on Indonesia's scientific ability to rank 70th out of 79 countries (Anshar et al., 2023; Nurhayati et al., 2023). From the results above, it can be concluded that the level of critical thinking skills in science learning of these students is still lacking.

Monotonous learning media makes students unable to solve the learning presented (Gusteti et al., 2023; Putri, D. P. et al., 2020). Therefore, it is necessary to have the right learning media and in accordance with the characteristics of students, especially in science learning. It is appropriate for learning media to adjust to student needs in order to make it easier for students to process knowledge information, stimulate students' thinking power and imagination, and share concrete knowledge for students. Through learning media, abstract material can be transformed into concrete according to the development of elementary school students (Suheryani et al., 2018; Tegeh et al., 2020). The development of media that contains audio and visual elements is guaranteed to make it easier for students to gain a good understanding of the material taught (Mellisa & Yanda, 2019; Usuf et al., 2017). Interactive learning media can facilitate students when receiving material such as in theme 9 science content with discussions of Single Substances and Mixed Substances. Cognitive skills in critical thinking skills will go hand in hand with independence in learning. Students will be able to correlate the knowledge gained with their behavior and application. This is then justified by research from Lestari et al that a low level of independence will affect the level of student learning ability so that students get decreased learning outcomes, do not have a high sense of care and make students depend on the surrounding environment to complete the tasks given (Yoon et al., 2020; Zainuddin & Perera, 2019). In addition to the low level of critical thinking skills in student science learning, there are also other problems in the form of low student learning independence. Based on the results of the questionnaire obtained that students have not applied learning independence and do not understand how to accommodate learning independence in the learning process in the classroom. Not only that, the results of observations made that teachers only create discussion forums, explain through Power Point and also video shows on YouTube for students. From the observations made, there are students who have not given a good focus on what the teacher displays, because the existing youtube and power point videos are only explanatory text without moving pictures or examples that can be real for students. During the learning process, there are students who are only busy alone, and teachers also cannot classify various ways of learning or learning styles of students.

Learning outcomes that must be met are students able to identify, analyze, distinguish, and be able to conduct experiments related to learning. In fact, each educational institution has received distribution of teaching materials from the government, but it has not been able to accommodate the learning methods of each child in grade V elementary school and also to improve critical thinking skills and learning independence. As for the learning process itself, it still focuses on the teacher, even though the orientation of the teaching process in the classroom is to accommodate the needs of students and teachers in learning, where they are the center of learning. The novelty of this study is to focus on the development of STEM-based animated learning videos designed to improve students' critical thinking skills and learning independence. From the problems that have been explained, researchers are finally encouraged to create an innovation that can be applied in the learning process in grade V with the K-13 curriculum using STEM-based animated learning videos. The development of STEM-based animated learning videos is expected to improve critical thinking skills and learning independence of grade V elementary school students because the videos developed have novelty in the form of meeting the needs of various student learning styles. This research and development aims to: (a) Know the feasibility of STEM-based animated learning video products; (b) Knowing the effectiveness of STEM-based animated

learning videos in improving critical thinking skills and learning independence of students in grade V elementary schools that have diverse learning styles; and (c) Knowing the practicality of STEM-based animated learning videos in improving students' critical thinking skills and learning independence in grade V elementary school.

2. METHOD

The study used the type of Research and Development (R&D) research, because this study aims to develop a learning product in the form of STEM-based Animated Learning Videos intended for grade V science learning in elementary schools. The model used is the development of the 4-D model. The 4-D (Four D) development model is a type of learning device development. This model was conceived and developed by previous research (Siagian et al., 2021; Ulva, 2017). The 4D development model consists of 4 main stages, namely: *Define*, *Design*, *Develop* and *Disseminate*. The define stages include the initial analysis process, task analysis, concept analysis, core competency analysis, basic competencies and learning objectives. The *design* stage is the process of designing developed media which is packaged in a grid which is then used as an instrument The stages include the preparation of animated learning video instruments, designing STEM-based animated learning videos (draft I), reviewing supervisors, revision I (draft II), validation of expert lecturers and science teachers. The *development* stage includes revision II (draft III), limited trials, field trials, and finally the *dessiminate stage,* namely the media dissemination process.

The research process was carried out in several elementary schools located in the Special Region of Yogyakarta. Researchers involve material expert lecturers, media experts, class teachers, and students as research subjects. Material experts and media experts conduct feasibility tests on STEM-based animated learning video media in improving critical thinking skills and learning independence. Furthermore, teachers and students were involved to assess the practicality of the STEM-based animated learning video media developed. After that, researchers conducted pretest and post tests on research subjects which included experimental classes (SDN Bhayangkara) and control classes (SDN Baciro and SDN Klitren). Student pretest and posttest results are used as score acquisition to measure the effectiveness of STEM-based animated learning videos in improving students' critical thinking skills and learning independence. Obtaining scores from due diligence using purposive sampling techniques. Then the value obtained from the media practicality test based on random sampling techniques, and for the performance of effectiveness values using pretest and posttest tests in experimental and control classes. The subject of research can be seen in the following Table 1.

Table 1. *Research Subjects*

No	Subjects	Role
1.	Material expert	Test material qualification
2.	Media expert	Feasibility test of STEM-based animated video media
3.	Teacher	Test practicality from the teacher's perspective
4.	Students	Test the practicality and effectiveness of media use by students

Data collection techniques are carried out through questionnaires, questionnaires and tests. There are 2 types of questionnaires, namely media literacy questionnaires and response questionnaires. Questionnaires, questionnaires and tests are used to obtain the results of the assessment of the developed media feasibility test, response questionnaires are used for practicality tests and tests are used to obtain effectiveness scores from students. The scale used in this research questionnaire has a rating scale with a scale of 1-5. The grids used are described in Table 2, Table 3 and Table 4.

Table *2*. Media Eligibility Grid

No	Assessment Aspects
1.	Appropriateness of content
2.	Language
3.	View
4.	Usefulness
5.	Closing

Table 3. Material Feasibility Grid

No	Assessment Aspects
1.	Clarity of learning competencies
2.	Suitability of learning materials with competencies
3.	Clarity of learning competencies
4.	Suitability of learning materials with the competencies
5.	Clarity user
6.	The attractiveness of the material in attracting students' interest in learning
7.	Clarity of the material presented
8.	Completeness of the material presented
9.	Continuous presentation of material
10.	The truth of the content of the material
11	Depth of content
12.	Audio suitability to the material
13.	Suitability of material in animated videos
14.	Accuracy of language use
15.	Clarity of evaluation questions
16.	Match the level of evaluation difficulty to user characteristics

Table 4. Media Practicality Grid

No	Assessment Aspects
1.	Clarity of media titles
2.	Letter legibility
3.	Color combinations
4.	Ease of media operation
5.	Audio and video quality
6.	Conformity helps understanding
7.	Media helps understanding the materials

In the multiple-choice type test question instrument before being used in the field, the quality is first examined, by meeting the quality of the content, then the multiple-choice type test question instrument is carried out by expert judgement by people who are experts in their fields, after that instrument trials are carried out to determine the validity (validity) and reliability (reliability) of the instrument, because the quality of the instrument must meet important requirements, namely: (a) validity of test items; (b) test reliability; (c) test differentiating power; and (d) test item difficulty. Hypothesis testing used correlated t-tests and the rendering of results with manual calculations. Before conducting a hypothesis test (correlated t-test), a prerequisite test (normality and homogeneity) is carried out.

3. RESULT AND DISCUSSION

Result

The results of this research are divided into four four parts, namely Define, Design, Development, and Disseminate. First, *Define* phase. In this stage, at this stage is carried out to establish and define the development requirements. The condition in question is something that is able to show the basic need why it is necessary to develop a learning video media at SDN Bhayangkara, SD N Baciro, and SDN Klitren. For this reason, 3 different analyses are needed to be able to find the subject matter that exists. The three types of analysis in question, namely: (a) initial analysis; (b) student analysis; (c) task analysis; (d) concept analysis; and (e) learning objectives analysis. At the initial analysis stage, in 5 elementary schools in thematic learning with science content for grade V with the 2013 curriculum, it was found that the learning process carried out still used the lecture method. In addition, there is also no use of interactive STEM-based learning media. At the analysis stage of students, the level of critical thinking skills and learning independence is still below standard. This can be seen at SDN Bhayangkara, SD N Baciro, and SDN Klitren found that the value of PTS (Midterm Assessment) is still below KKM. The achievement of KKM should be with a score of 73 in elementary science lessons, but the average student obtained is only 49.34% who achieve KKM. In learning independence, from the results of the questionnaire obtained that students have not applied learning independence and do not understand how to accommodate learning

independence in the learning process in the classroom. Another finding obtained is that teachers only create discussion forums, explain through Power Point and also video shows on YouTube for students. In the task analysis, the materials used by SDN Bhayangkara, SD N Baciro, and SDN Klitren were single substances and mixed substances. The basic competencies and indicators used in such schools can be observed in Table 5.

Table 5. Basic Competencies and Indicators used by SDN Bhayangkara, SDN Baciro, and SDN Klitren

Basic Competencies	Indicators
3.9 Grouping objects in daily life according to their constituents (single substances and mixed substances)	3.9.1 Categorize objects into elements or compounds 3.9.2 Analyze the types of heterogeneous mixtures and homogeneous mixtures 3.9.3 Analyze the relationship between homogeneous and heterogeneous mixed substances with daily life 3.9.4 Evaluate various kinds of single substances and mixed substances 3.9.5 Formulate a solution that can be used to detect single substances and mixed substances
4.9 Report the results of observations of the properties of mixtures and their components in daily life	4.9.1 Conduct experiments on heterogeneous and homogeneous mixtures 4.9.2 Create homogeneous and heterogeneous mixtures 4.9.3 Write an evaluation report on the results of monitoring the properties of mixed materials and their components in daily life

At the concept analysis stage, the concepts of single-substance matter and mixed substance include elements and compounds, single substances, homogeneous substances, heterogeneous mixed substances, and their application and life. The concept became material in designing videos developed by researchers. At the learning objectives stage, the learning objectives used by SDN Bhayangkara, SDN Baciro, SDN Klitren, and SDN Demangan are: (a) explaining the difference between single substances and mixed substances; (b) analyze the types of elements and compounds; (c) describe objects in the student's environment that belong to a single substance that can be found in everyday life; (d) Evaluate the various types of single substances and zampur that are often encountered; and (e) formulate ideas for solutions that can be used in detecting single substances and mixed substances. The learning objectives used by the five elementary schools are also a consideration for researchers in designing STEM-based animated learning videos.

Second, *Design Phase*. The *design* stage applied in this study includes the preparation of instruments, media selection, and format selection. At the instrument preparation stage, the instruments used are animated video assessment sheets for material expert lecturers, animated video assessment sheets for expert lecturers, practical video analysis sheets for grade V teachers, breadth of student response questionnaires, and four instruments in the form of content feasibility, technical feasibility, and media feasibility. The critical thinking assessment instrument in the form of pretest and post-test questionnaires includes indicators of understanding, analysis and evaluation. The indicators of learning independence include designing, monitoring, controlling, being responsible, taking action on self-awareness, and self-control. At the media selection stage, the media used is derived from the needs of the initial analysis results. The media used are single substance and mixed substance LKPD, single substance and mixed substance material videos, LCD, projectors, and loudspeakers. In choosing the format, the format applied to the STTEM-based animated learning video developed includes the title format, core competencies and basic competencies, competency achievement indicators, learning objectives and STEM components, namely *science, technology, engineering, and mathematic.* Furthermore, researchers made an initial design of STEM-based animated learning videos based on the selected compatibility, namely in the form of competence in grouping objects in everyday life according to the arrangement (single substances and mixed substances) and reporting the results of observations of mixed properties and their components in everyday life. Based on the selected competencies, STEM-based animated learning videos developed by researchers were divided into three activities, namely activities on single-substance material and explanation of compounds and elements, activities on homogeneous and hetergone mixed materials and experimental activities that will be carried out by students.

Third, *Development Phase.* At this stage of development, researchers carry out a number of steps such as product feasibility, product effectiveness, and product practicality. In order to determine the feasibility of STEM-based animated learning video products, STEM-based animated learning videos are tested for feasibility by material experts and media experts. Product eligibility results can be seen in the following Table 6.

Table 6. The Result of Product Feasibility

No	Expert	Score	Category
1.	The Material Expert	91.7	Very Good
2.	The Media Expert	80	Good

Data in Table 6 shows that STEM-based animated learning video media products by material experts showed a score of 91.7 in the very good category and media experts gave a value of 80 in the good category. Based on the table above, it can be concluded that STEM-based animated learning video products are declared feasible based on expert assessments. In product effectiveness, the effectiveness of animated learning videos is described based on two types, namely descriptively through comparison of average values and hypothetically through inferential statistical tests in the form of t tests. The effectiveness of this animated learning video is related to improving critical thinking skills and learning independence. Before being tested with statistics, the results of critical thinking skills and learning independence in experimental and control classes were first tested for normality and homogeneity. The results of the normality and homogeneity test can be seen in Table 7 and Table 8. Based on Table 7, it can be concluded that the critical thinking and self-directed learning variables in the experimental and control classes are normally distributed because the significance obtained is more than 0.05.

Table *7*. The Normality Test Result

Variable	Type of Test	Group	Sig	Decision
Critical Thinking	Pretest	Eksperiment	0.200	Normally distributed
		Control	0.200	
	Posttest	Eksperiment	0.200	
		Control	0.200	
Self-Directed Learning	Pretest	Eksperiment	0.200	
		Control	0.200	
	Posttest	Eksperiment	0.200	
		Control	0.200	

Table *8.* The Homogenity Test Result

Variable	Type of Test	Sig	Decision
Critical Thinking	Pretest	0,103	Homogen
	Posttest	0,141	
Self-Directed Learning	Pretest	0,177	
	Posttest	0,180	

Based on Table 8, it can be concluded that the critical thinking and self-directed learning variables in the pretest and posttest can be said to be homogeneous because the significance obtained is more than 0.05 so it can be concluded that there is no difference in variance between the experimental group and the control group on the critical thinking and self-directed learning variables. The comparison of the average scores on the results of the critical thinking ability test and self-directed learning questionnaire in the experimental group and control group is seen in Table 9.

Table 9. The Average Test Result of Effectiveness Product

	Critical Thinkig		Self-Directed Learning	
	Eksperiment Group	Control Group	Eksperiment Group	Control Group
Pretest	59.31	48.55	35.14	27.14
Posttes	79.62	67.14	43.62	37.05

Based on Table 9, it can be concluded that critical thinking skills and self-directed learning have increased significantly in the experimental class that uses animated learning videos. So, it can be stated that STEM-based animated learning videos are effective in improving critical thinking skills and self-directed learning. The effectiveness of STEM-based animated learning videos can be seen in Table 10. Statistically, the effectiveness of STEM-based animated learning videos is reviewed based on statistical results using the SPSS application. The results of the statistical test have met the prerequisite criteria,

namely the normality and homogeneity test. So it is continued on the manova test, independent t test, and n gain test. The results of the hypothesis can be seen in the following table.

Table 10. Product Effectiveness Hypothesis Test Results

No	Type of Test	Sig
1.	Manova	0.000
2.	Independent sample t-test (critical thinking)	0.000
3.	Independent sample t-test (self-directed learning)	0.000

Based on Table 10, it can be concluded that the significance value in the three tests is below 0.05, which means there is a significant difference between the experimental group and the control group. This means that there are significant differences in the critical thinking skill and self-directed learning who use STEM-based animated learning videos, there are differences in critical thinking between students who use STEM-based animated learning videos and students who do not use STEM-based animated learning videos, and there are differences in self-directed learning between students who use animated STEM learning videos with students who do not use STEM-based animated learning videos. In the practicality test, the practicality of STEM-based animated learning videos was obtained from the results of teacher assessments and student assessments of the product and the results of observations of learning implementation. The practical results obtained can be seen from Table 11.

Tabel 11. Product Practicality Test Results

No	Aspect	$\bar{X}$	Category
1.	Penilaian Guru	88	Very Good
2.	Penilaian Siswa	92.8	Very Good
3.	Observasi	100	Very Good

Based on the Table 11, the results obtained from assessing the practicality of STEM-based animated learning video products are stated to be practical for use in science learning in class V on single substance and mixed substance material. *Fourth, Diseminate phase.* The tool improvement stage is carried out with implementation stage steps. This stage aims to publish animated educational videos based on science, technology, engineering, and mathematics (STEM). In this study, the socialization carried out was of a certain nature, namely socialization and promotion of the final product of learning media in the form of STEM-based animated educational videos to grade 4 elementary science teachers on a limited basis. The dissemination of science learning videos has only been carried out in one school, namely at SDN Bhayangkara, SD N Baciro, and SDN Klitren. It is hoped that STEM-based animated learning videos in this differentiation of various learning styles can be disseminated and used in learning in other schools.

Discussion

STEM-based learning videos applied to this learning consist of science, technology and engineering. The concept of science is knowledge about nature and its environment which includes applicable rules and concepts. Technology in STEM is the skill of using and creating technology as a tool in making it easier to solve problems, engineering is the knowledge to create or design a work system to solve problems, and mathematics is the science of magnitude, numbers and space and the relationships between them that require synthetic reasoning with or without empirical evidence (Kelley & Knowles, 2016; Wu & Rau, 2019). Science trials conducted by students can help students to improve their understanding of science learning. This is supported by Johnson's opinion that STEM learning must (a) use students' real-life projects or problems so that learning is more meaningful; (b) challenge the potential of students in applying engineering design approaches to foster critical and creative thinking; (c) assisted by engineering design So that students can take learning from unsuccess in finding solutions; (d) carry out learning by integrating science, mathematics and other related subjects such as art, humanities literature, and social studies; (e) carry out learning activities with students as learning centers and be actively involved in learning activities; and (f) encourage Collaboration and communication between students in learning activities (Johnson et al., 2021). Based on the results of the study that there is a significance of the use of STEM-based animated learning videos on students' critical thinking skills. These results are supported by research by Nurilma, which states that STEM-based learning videos can improve students' critical thinking skills (Nurilma et al., 2023; Zulhelmi et al., 2023). This is also in line with Parno's opinion that the improvement of students' critical thinking skills is influenced by learning circumstances before using STEM and after using STEM. Students will be much better and more effective in following learning if

they use STEM-based animated learning videos. STEM-based animated learning videos also have an impact on the construction of students' critical thinking skills (Haryandi et al., 2019; Winarti, W. et al., 2021). In order for teachers to provide teaching that has an impact on students' critical thinking skills, teachers must have a strong understanding of everything contained in each component of students' critical thinking skills (Dumitru, 2019; Sellars et al., 2018). Teachers must believe that STEM learning is beneficial for children's education and growth, including the development of children's critical thinking skills (Çiftçi et al., 2022; Ültay & Ültay, 2020). In addition, research suggests seminars, workshops, conferences, and competitions are structured and designed around STEM learning themes that focus on interdisciplinary and transdisciplinary learning and teaching developing children's critical thinking skills (Abu Khurma et al., 2022; Takeuchi et al., 2020). Nonetheless, students' critical thinking skills are directly related to teachers' views on STEM learning, teachers assume that STEM learning will contribute to children's critical thinking skills directly (Gencer & Doğan, 2020; Hacioglu & Gulhan, 2021). Critical thinking includes many skills that develop at different rates depending on the cognitive maturity and level of development of the child. Critical thinking skills stimulate the child to observe and process the information received and eventually convert it into an attitude (Rahayu et al., 2023; Sochacka et al., 2016). The ability to think critically will also encourage children to become problem solvers (Albay, 2019; Bradshaw & Hazell, 2017). STEM focuses on solving relevant problems through transdisciplinary integration of different fields of science using strategies such as inquiry-based instruction, problem-solving, critical thinking and collaboration (Ortiz-Revilla et al., 2020, 2022). Critical thinking is one of the most important skills of the 21st century, and is necessary to compete today (Basri & As' ari, 2019; Kania et al., 2023). For this reason, the individual becomes aware and evaluates and discusses his ideas with others in the process of critical thinking (Kuhn, 2019; Nasution et al., 2022).

Pada variabel kemandirian belajar siswa, secara keseluruhan kemandirian belajar peserta didik mengalami peningkatan. Pada kelas eksperimen hasil penilaian observer bahwa mengalami peningkatan pada kemampuan mandiri belajar sebanyak 87%. Terlebih saat melakukan uji coba STEM, terlihat peserta didik memenuhi kriteria penilaian kemandirian belajar. Dengan menggunakan video pembelajaran animasi berbasis STEM membuat peningkatan pada kemandirian peserta didik. Hasil tersebut didukung oleh penelitian Argianti & Andayani yang menyebutkan bahwa terdapat pengaruh pendekatan berbasis STEM terhadap kemandirian belajar siswa (Argianti & Andayani, 2021; Assagaf, 2016). One of the influences of STEM-based learning animation videos on student learning independence is caused by content. The content presented in the video is also tailored to the curriculum and student needs, making it easier to understand and relevant to everyday life. In addition, the use of technology in learning is also one of the determining factors in increasing student learning independence (Abidin et al., 2024; Hamidi & Chavoshi, 2018). With STEM learning videos, students can learn independently by accessing these videos anytime and anywhere according to their needs. This allows students to set their own study time and gain control over the learning process. STEM learning also provides opportunities for students to learn visually and interactively. The material presented in visual form is easier for students to understand. While interactive features like quizzes and self-paced exercises can help test their understanding live. Thus, students can learn in a more fun and interesting way so as to increase their independence in the learning process.

However, the independence of learning owned by students needs to be done habits every day, there must be habits built so that students are able to apply learning independence in themselves. The ability to learn independence includes students' habits of solving their own problems, having initiative, being able to work together, being able to provide full awareness that students are also independent humans who can facilitate themselves, and have high self-confidence. This is also supported by the results of Morris' research that independent learning is a way of learning that gives great responsibility to every student to gain freedom in acquiring knowledge (Morris, 2019; Voskamp et al., 2022) Murniati also in his research suggested that learning independence is one of the factors for students to obtain achievements that come from external students. Learning independence makes students learn with their own encouragement not by coercion (Murniati et al., 2023; Ningsih & Nurrahmah, 2016) . The results of this study make an important contribution to understanding the influence of the use of STEM-based animation learning videos on students' critical thinking skills and learning independence. This study shows that animation-based media integrated with STEM approaches can significantly improve students' critical thinking skills as well as encourage their independence in the learning process. The application of this STEM-based animation video shows how a creative and interactive approach can enrich the learning process and improve student learning outcomes. This could be the basis for further research on how technology can be integrated in education to build 21st century skills such as critical thinking and learning independence. One of the limitations of this research is that it does not cover the long-term aspects of the use of this media on the development of students' abilities. External factors such as technology access and

school infrastructure readiness may not be fully covered in this study, which affects the equitable application of STEM-based media. Recommendations for further research include a more in-depth examination of the long-term impact of the use of STEM-based animated videos on student skills, as well as how these technologies can be accessed and applied more broadly in a variety of educational contexts.

4. CONCLUSION

Based on the results of data analysis and discussions that have been carried out, it can be concluded that: (1) The STEM-based animated learning videos developed are suitable for use in grade V science learning to improve critical thinking and learning independence of elementary school students; (2) STEM-based animated learning videos in effectively improving critical thinking skills and learning independence of grade V elementary school students; (3) Practical STEM-based animated learning videos are used by teachers and grade V elementary school students in improving critical thinking skills and learning independence of grade V elementary school students

5. REFERENCES

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