JURNAL EDUSCIENCE (JES)
p-ISSN : 2303 - 355X | e-ISSN : 2685 - 2217
PUBLISHED BY : LPPM of UNIVERSITAS LABUHANBATU

Jurnal Eduscience (JES)
Volume 11, No. 3
December, Year 2024
Submit : 20 November 2024
Accepted : 27 Desember 2024

DIGITAL PEDAGOGY IN PRIMARY EDUCATION: DEVELOPING SIPEJAR MICROLEARNING TO CULTIVATE CRITICAL THINKING SKILLS

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Abstract
This study aims to develop SIPEJAR-based microlearning modules and evaluate their effectiveness in enhancing critical thinking skills among Primary School Teacher Education (PGSD) students. Employing the ADDIE development method (Analysis, Design, Development, Implementation, Evaluation), the study included expert validation of the module content and its implementation involving 76 students divided into experimental and control groups. The results revealed that integrating SIPEJAR-based microlearning significantly improved critical thinking skills in the experimental group, with a statistically significant difference in post-test scores compared to the control group ($p < 0.05$). Key success factors included modular design, interactive multimedia, and flexible access. This research offers significant benefits to educators, particularly prospective primary school teachers, equipping them with digital pedagogical strategies to prepare students for global challenges. Additionally, this approach serves as a reference for digital learning innovations at other educational levels. The study highlights technology's role as a catalyst for 21st-century learning, fostering interactive, relevant, and adaptive learning environments

Keywords: microlearning, critical thinking, SIPEJAR, elementary school

INTRODUCTION

The rapid digital transformation in education has created both opportunities and challenges for educational systems, particularly at the primary level. The urgency to integrate technology into learning processes has become increasingly apparent, especially in preparing students to face the fast-paced information era (Batdı et al., 2024; Burns et al., 2024). Critical thinking skills are now an essential 21st-century competency that must be cultivated from an early stage (Alwan, 2022; Rahmawati & Atmojo, 2021). However, observations at the research site, namely the Primary School Teacher Education (PGSD) program at Malang State University, reveal that conventional teaching methods still dominate. This is evidenced by the minimal use of technology in teaching and learning processes and the lack of focus on

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PUBLISHED BY : LPPM of UNIVERSITAS LABUHANBATU

developing critical thinking skills.

Field observations and interviews with lecturers and students highlighted several key challenges. One major issue is the lack of teaching materials relevant to the needs of the digital generation. PGSD students often struggle to deeply understand critical thinking concepts due to one-directional teaching methods and limited interactivity. This underscores the need for a new pedagogical approach that is more adaptive to the characteristics and needs of today's generation.

Digital pedagogy involves the strategic use of digital technology to support the learning and teaching process (Septiana & Hidayati, 2022). This approach not only focuses on the use of digital tools but also encourages students to analyze, create, and utilize information critically (Setyaningsih & Prihantoro, 2018). This is in line with the goals of critical pedagogy which aims to empower students to question and challenge applicable norms and assumptions (Alwan, 2022). In the context of basic education, digital pedagogy can provide interactive learning experiences that encourage active engagement and the development of critical thinking skills (Kumar, 2019; Wendi, 2020).

One of the effective strategies in digital pedagogy is microlearning, which is the delivery of content in small, focused segments (Susantini et al., 2014). This strategy is perfect for students' attention span limitations and allows for flexible and independent learning. By presenting information in small modules, microlearning improves retention and comprehension, thus supporting the development of critical thinking skills (Sarimanah et al., 2021; Suriani et al., 2020). Research shows that microlearning significantly improves student engagement and their ability to critically apply knowledge (Hesti Lilis Setyawati et al., 2020; Sirwan Mohammed et al., 2018).

To address this urgency, this study proposes the development of microlearning modules based on the SIPEJAR (Learning Management System) platform. Microlearning is a learning approach designed to deliver content in focused, small segments, enabling students to gradually understand and apply materials. This approach excels in flexibility, interactivity, and the ability to improve information retention. Moreover, the SIPEJAR platform provides a structured and technology-based learning environment, allowing students to access materials independently anytime and anywhere.

This approach is supported by various prior studies. Farhan M et al., (2024) and Burns et al., (2024) affirm that microlearning effectively enhances students' cognitive skills in the digital era. Research by (Abdurrahman et al., 2023) demonstrates that integrating microlearning into STEM education significantly improves students' analytical abilities. Other research has shown that microlearning provides better results in concept retention (Shail, 2019), increases student learning motivation (Nikou & Economides, 2018; Shail, 2019), improves collaborative learning (Reinhardt & Elwood, 2019), microlearning also showed a significant improvement in students' analytical abilities (Abdurrahman et al., 2023; Saad et al., 2024). Similarly, the integration of critical thinking indicators in microlearning modules was shown to improve students' cognitive engagement and reflective thinking (Purnasari & Sadewo, 2021; Riyanto et al., 2013). Additionally, studies by De Gagne et al., (2019); Sirwan Mohammed et al., (2018) (Suriani et al., 2020) reveal that microlearning boosts student engagement in the learning process. However, these studies have not specifically addressed how microlearning can be used to develop critical thinking skills in the context of primary education or teacher candidates.

This study contributes novelty by focusing on developing critical thinking skills among PGSD students through the integration of microlearning on the SIPEJAR platform. Unlike previous studies, which largely highlighted general aspects of microlearning (Prestiadi et al., 2020; Sutadji et al., 2020; Ulupui et al., 2021), this research specifically develops expert-validated modules implemented in a measurable manner. Another innovation lies in the holistic approach that combines modular design, interactivity, and access flexibility to support active learning (Indrasvari, Harahap, and Harahap 2021).

The integration of microlearning into digital learning platforms such as SIPEJAR (Learning Management System) offers a great opportunity to empower critical thinking skills in basic education. SIPEJAR provides a structured learning environment that allows students to access micro-learning modules interactively. This approach not only supports the development of critical thinking skills but is also relevant to the needs of 21st century digital competencies (M et al., 2021; Yansaputra & Pangestika, 2018).

For prospective educators, such as students at the Elementary School Teacher Education Study Program (PGSD), mastery of digital pedagogy and microlearning strategies is very important. Aspiring teachers need to have the ability to integrate technology into their teaching practices to support the development of critical thinking skills in students (Purnasari & Sadewo, 2021). Learning in the use of platforms like SIPEJAR equips them with the skills necessary to design and implement microlearning experiences that encourage analytical and reflective thinking (Julianti, Harahap, and Safitri 2022).

This study aims to develop SIPEJAR-based microlearning modules that are valid and effective in improving the critical thinking skills of PGSD students. The findings are expected to make a tangible contribution to digital pedagogy innovation by creating learning approaches that are relevant, interactive, and adaptive to 21st-century educational needs. In the long term, this study hopes to serve as a model for the development of educational technology across various levels of education while addressing research gaps in using microlearning to enhance critical thinking skills (Maulana, Harahap, and Safitri 2022). Consequently, this research provides a strong foundation to support the transformation of technology-based education for the future.

METHODOLOGY

This research uses a type of development research (Research and Development) with the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model approach (**Figure 1**. The ADDIE Concept). This model was chosen because it provides a systematic framework for designing and evaluating the development of microlearning content in the SIPEJAR platform, thus fulfilling the aspects of validity and effectiveness. The stages in this study are as follows:

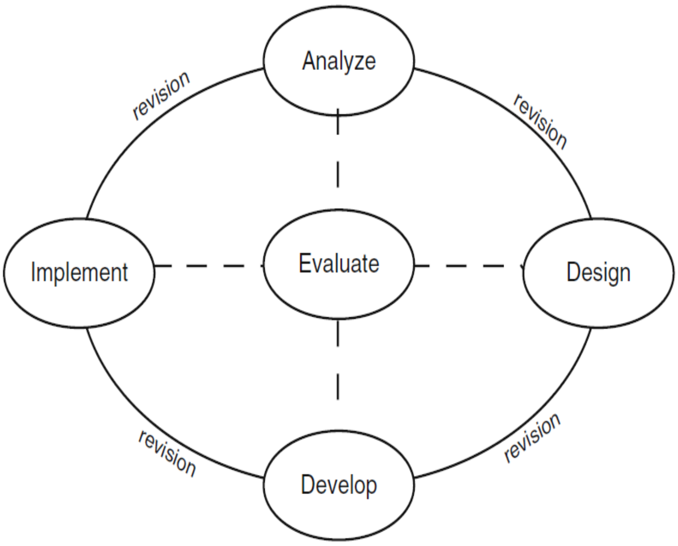

Figure 1. The ADDIE Concept (Branch, 2009)

1. Analysis

At this stage, a needs analysis was carried out through interviews with students at the Elementary School Teacher Education Study Program (PGSD) and lecturers of related courses. This analysis aims to a) Identify student needs in digital-based learning; b) Exploring the limitations of conventional learning in empowering critical thinking skills; c) Determine the relevant critical thinking content and indicators to be included in the microlearning module.

2. Design

This stage involves designing an initial prototype of the SIPEJAR microlearning module. The design process includes a) Determining the structure of microlearning content consisting of short materials, interactive videos, quizzes, and analysis-based tasks; b) Design a user-friendly and easy-to-use interface; c) Prepare pre-test and post-test questions to measure critical thinking skills.

3. Development

This stage focuses on developing micro-learning content based on design results. The SIPEJAR-based microlearning modules were developed using Canva and Camtasia software over a two-month period. Each phase of the ADDIE model had a designated timeline: analysis (two weeks), design (three weeks), development (four weeks), implementation (four weeks), and evaluation (two weeks). The resources included video lectures, quizzes, and interactive tasks designed to promote critical thinking.

The content is tested for validity by experts, which involves digital pedagogical experts and instrument experts. Validation is carried out to ensure the quality of the content, the clarity of the modules, and the suitability with the learning objectives. This stage is also revised based on input from experts to improve the quality of content.

4. Implementation

SIPEJAR's validated microlearning content is implemented in learning in two PGSD classes: a) Experimental classes using SIPEJAR with a microlearning approach; and b) The control class uses

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p-ISSN : 2303 - 355X | e-ISSN : 2685 - 2217
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conventional learning methods without microlearning. The implementation process lasted for 4 weeks by obtaining equivalent materials. The participants consisted of 76 PGSD students and three lecturers from Malang State University. The sampling process used a purposive sampling technique, selecting students enrolled in relevant courses and lecturers with expertise in digital pedagogy. The experimental group included 38 students who used the micro-learning modules, while the control group of 38 students participated in conventional learning sessions. The demographic information revealed balanced gender distribution and diverse academic performance backgrounds among participants. Conventional learning in this study refers to traditional face-to-face teaching methods involving lectures, textbook-based assignments, and minimal use of digital tools. This mode emphasized content delivery without structured activities to foster critical thinking explicitly.

5. Evaluation

The evaluation was carried out to assess the effectiveness of SIPEJAR's microlearning content based on the results of the critical thinking skills post-test. Ennis's framework of critical thinking, emphasizing clarity, accuracy, and logical reasoning, was used to design post-test items. The assessment consisted of 15 multiple-choice questions with supporting texts and scenarios relevant to the PGSD curriculum. The study used an independent sample T-test to compare the post-test results of the experimental and control groups. Assumptions of normality and homogeneity of variance were tested using Kolmogorov-Smirnov and Levene's tests, respectively, to ensure validity.

This ADDIE stage is designed to ensure that the development of SIPEJAR microlearning is not only valid in content, but also effective in improving the critical thinking skills of PGSD students. By incorporating these details, the methodology provides a transparent and replicable framework for future studies, ensuring clarity in participant selection, assessment design, and analytical rigor.

RESULT AND DISCUSSION

Result

Multimedia Expert Validation Data

The SIPEJAR content developed contains multimedia, both video and power point material. The following Table 1 is the result of the multimedia revision used in the SIPEJAR Content.

Table 1. Multimedia Revision Results

Types of revisions/feedback	Before it is revised	After revision
Monotonous and unattractive font selection	The use of typefaces and font colors is not yet interesting	The choice of font and font color is already interesting
Presentation of concepts is less detailed	Explanation of material is not detailed	The material is detailed and clear
The color quality of the image is not suitable	Image color selection with small pixel sizes	The color of the image used has a large pixel size and is appropriate
Audio is unclear	Audio is not at its maximum	Audio usage syncs with speaker quality

The revisions were guided by expert feedback to address initial shortcomings and enhance the effectiveness of the multimedia components in engaging learners and facilitating critical thinking

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development. (1) Font Selection, the initial font choice was deemed monotonous and unappealing, potentially reducing learner engagement. To address this, the revised modules used fonts with better readability and an attractive color scheme. This change was intended to improve visual appeal and maintain learner interest throughout the module; (2) Concept Presentation, feedback indicated that the explanations in the original modules lacked detail and clarity, which could hinder understanding of critical concepts. Post-revision, the content included more detailed and structured explanations. This was achieved by breaking down complex ideas into smaller, digestible parts, ensuring alignment with the principles of microlearning; (3) Image Quality, low-resolution images were identified as a detriment to the overall visual quality of the modules. High-resolution images with well-balanced colors were incorporated, creating a more professional and visually engaging presentation; (4) Audio Quality, the original audio was unclear and lacked synchronization with the visual components, which disrupted the learning experience. Revised audio files were professionally edited to ensure clarity and synchronization, enhancing the multimedia's cohesiveness and accessibility.

These revisions collectively improved the overall learning experience, addressing both aesthetic and functional aspects of the modules. The enhanced multimedia not only aligned with pedagogical standards but also supported the engagement and critical thinking development of learners. By incorporating expert suggestions, the modules met the expectations of modern digital learning environments.
The results of multimedia validation are presented in the following Table 2.

Table 2. Validation of Multimedia Expert

Assessment Aspects	Score	Classification
Font selection or font type and size	4	Good
Image or illustration size	5	Excellent
Video views enrich information	5	Excellent
Audio quality	5	Excellent
Compatibility of text, images, tables and videos	5	Excellent
Illustrations and drawings help with concept understanding	4	Good
Video fit with material	4	Good
Average	**4,6**	**Excellent**

While the average score of 4.6 places the multimedia in the "Excellent" category, certain aspects, such as font selection and video fit with the material, received slightly lower scores. Font Selection (Score: 4 - Good): Experts noted that although the revised font selection was a significant improvement, there remains room for further refinement to align with accessibility standards and maintain consistency across all modules. Video Fit with the Material (Score: 4 - Good): Feedback suggested that some videos could be better tailored to complement the material’s specific learning objectives. Future iterations could involve integrating more targeted video content that directly supports the critical thinking indicators being taught. These observations highlight areas for continuous improvement, ensuring that the multimedia remains effective and engaging for learners. Addressing these points will help achieve a fully optimized learning experience in future implementations.

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Cognitive Instrument Expert Validation Data

In addition to multimedia validated by experts, the same thing on the items of cognitive instruments that measure critical thinking skills is also validated to experts. The total number of instruments developed was 15 multiple-choice questions with three diverse readings. Some notes from experts related to the items of instruments developed to measure critical thinking skills are (1) the readings used should not be too long so as not to be boring; (2) the choice of sentences in the answer choice must have relatively the same word length; (3) the distribution of answer keys must be even and not monotonous on only one answer key; (4) avoid using sentences with double meanings; (5) if there is already a reading, it is better to use short question sentences only; (6) the use of readings should be varied and avoid readings in the form of the same paragraphs or can be replaced with dialogue readings and the like; and (7) ensure that the indicators or learning objectives used are really in accordance with the indicators of critical thinking.

Several notes given by experts are the main factors in improving the instrument items. After the revision, all instruments are in accordance with the purpose of their development, which is to measure critical thinking skills. The following Table 3 is the results of validation from cognitive instrument experts.

Table 3. Validation of Cognitive Instrument Experts

Assessment Aspects	Score	Classification
Question items using good and correct Indonesian	5	Excellent
The question item does not use terms in a specific area	5	Excellent
The subject matter is free from double interpretation	4	Good
The main points of the problem are formulated briefly and clearly	5	Excellent
The material on the question items has been studied by students	4	Good
Question items using communicative language	5	Excellent
The answer to the question item does not depend on the answer to the other question item	5	Excellent
The answer key in the question item is correct	4	Good
Question items in accordance with the indicators to be achieved	5	Excellent
Average	**4,7**	**Excellent**

The expert feedback highlighted several areas for improvement, which were directly addressed in the final version of the instrument: (1) Sentence Length and Clarity: Initially, some question stems were overly lengthy, potentially causing confusion. For example, a question stem that read: "Based on the reading, explain how the main character's decisions reflect their understanding of ethical principles" was revised to: "How does the main character's decision show their ethical understanding?" This change ensured conciseness and improved readability; (2) Distribution of Answer Keys: The initial distribution was skewed, with a higher frequency of correct answers being assigned to a single option (e.g., option C). The final version ensured a balanced distribution of correct answers across all options, reducing predictability and enhancing the instrument's reliability; (3) Variations in Question Formats: Experts suggested diversifying question formats to maintain student engagement. Consequently, some multiple-choice questions were supplemented with scenario-based questions requiring application and analysis, aligning more closely with critical thinking indicators; (4) Avoidance of Ambiguity: Feedback indicated that some questions could be interpreted in multiple ways. For instance, a question initially phrased as:

"What is the best solution to the problem?" was revised to: "According to the passage, which solution addresses the problem most effectively?" This adjustment eliminated ambiguity and ensured alignment with the intended learning objectives.

By incorporating these improvements, the cognitive instruments were refined to provide a clearer, fairer, and more robust assessment of critical thinking skills. These revisions strengthened the validity and reliability of the instruments, ensuring they effectively measure the intended competencies.

SIPEJAR Content Effectiveness Test Data

The effectiveness test aims to determine the effectiveness of SIPEJAR microlearning content based on the achievement of learning outcomes, in this case critical thinking skills. To conduct an effectiveness test, final test data (*post-test*) is needed as material for independent *sample T-test analysis*. Before the data is tested T, it is necessary to fulfill the prerequisite tests, namely the normality test and the homogeneity test on the initial and final test data. Table 4 is the results of the normality test of the initial test and the final test of the effectiveness test.

Table 4. Normal Test Results

	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Control	.122	38	.165	.948	38	.075
Experiment	.111	38	.200*	.946	38	.068

Based on Table 4 shows that the level of observational significance (P) is greater than 0.05 = α for both the control class data tested using Kolmogorov-Smirnova (P = 0.165 > 0.05 = α) and those tested using Shapiro-Wilk (P = 0.075 > 0.05 = α) for the control class. Similarly, for the experimental class (P = 0.200 > 0.05 = α) tested with Kolmogorov-Smirnova and (P = 0.068 > 0.05 = α) tested using Shapiro-Wilk. The significance values (Sig.) for both the control and experimental groups are greater than 0.05 for both normality tests. This indicates that the data for both groups follow a normal distribution, meeting one of the key assumptions for conducting a T-test.

To ensure the variance of the data was consistent between groups, a homogeneity test was performed. The results are summarized in Table 5 below.

Table 5. Homogeneity Test Results

Levene Statistic	df1	df2	Sig.
2.038	1	74	.158

Based on Table 5, the significance value (Sig.) of 0.158 is greater than 0.05, indicating that the variances between the control and experimental groups are homogeneous. This satisfies another assumption required for performing a valid T-test. Here are the descriptive data from both classes which can be viewed in detail in Table 6 below.

Table 6. Descriptive Data of the Second Class

Treatment Class	N	Mean	Std. Deviation

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p-ISSN : 2303 - 355X I e-ISSN : 2685 - 2217
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Critical Thinking	Control	38	79.2105	2.96062
	Experiment	38	89.1316	2.47333

The following Table 7 is the results of the analysis of the T-test (*independent sample T-test*).

Table 7 T-Test Analysis Results

		t	df	Sig. (2-tailed)	Mean Difference
Critical Thinking	Equal variances assumed	-15.853	74	.000	-9.92105

As shown in Table 7, the T-test produced a significant value (Sig.) of 0.000, which is less than 0.05, indicating a statistically significant difference between the two groups. The negative t-value (-15.853) and the mean difference of -9.92 suggest that the experimental group scored significantly higher than the control group. This confirms the effectiveness of the microlearning modules in enhancing critical thinking skills.

Discussion

SIPEJAR Microlearning is a learning management system designed to manage learning both online and offline. The embryo of this management emerged in 2010-2014 along with the rapid and rapid development of information technology which began with the outbreak of online learning interaction (Zawacki-Richter & Naidu, 2016). Since March 2020, the beginning of the pandemic has forced all education sectors around the world to carry out distance learning to break the chain of the spread of Covid-19. This is the driving force to continue to be creative and innovative in creating new things in learning even though it is carried out online and remotely.

The results of this study demonstrate the effectiveness of SIPEJAR-based microlearning in enhancing critical thinking skills among PGSD students. The significant mean difference in post-test scores between the experimental and control groups (mean difference = 9.92, $p < 0.05$) highlights the platform's potential in fostering higher-order thinking. This improvement can be attributed to the modular and interactive design of the SIPEJAR platform, which supports focused and autonomous learning. These findings are in line with previous research that emphasized the effectiveness of microlearning in improving students' cognitive skills in a digital context (Farhan M et al., 2024; Prestiadi et al., 2020; Sutadji et al., 2020).

The improvement of critical thinking skills in experimental classes can be attributed to microlearning designs that present content in small, focused segments, allowing students to digest information more effectively (Nuraisyah, Harahap, and Harahap 2021). This approach also encourages independent and reflective learning, which is essential in the development of critical thinking skills. Additionally, the use of interactive elements in microlearning modules increases student engagement, which contributes to a deeper understanding and the ability to critically apply knowledge. A mean score improvement of nearly 10 points in the experimental group indicates that students not only engaged with the content more effectively but also developed the analytical and evaluative skills targeted by the curriculum. This suggests that microlearning, particularly through SIPEJAR, provides a viable alternative to traditional teaching methods in addressing critical thinking gaps in primary education teacher training.

The implementation of microlearning through SIPEJAR also provides flexibility in the learning process, allowing students to access materials according to their own pace and schedule. This flexibility not only increases learning motivation but also allows students to allocate enough time to analyze and reflect on the material, which in turn strengthens their critical thinking skills. This is consistent with findings suggesting that microlearning can increase student motivation and engagement in online learning environments (Farhan M et al., 2024; Prestiadi et al., 2020; Sutadji et al., 2020). Critical thinking is not new, but its application is still not optimal, especially for elementary school students whose thinking skills are still in the concrete thinking stage (Piaget & Kohler, 2014). Prospective elementary school teachers must be taught these kinds of things from an early age because these skills will be widely used in the 21st century.

The very significant difference in critical thinking results is caused by various factors, one of which is the multimedia content developed. The inclusion of multimedia components such as high-quality images, interactive quizzes, and synchronized audio contributed to engaging learners and improving their retention and critical thinking skills (Rosydiana et al., 2023; Setyarini et al., 2022; Utama et al., 2023). These elements are aligned with cognitive load theory, ensuring that students process information effectively without becoming overwhelmed. The results of media validation conducted by experts show that SIPEJAR microlearning has excellent quality with an average score of 4.6. This assessment is based on seven mutually supportive aspects to ensure that SIPEJAR microlearning is effectively used in the development of critical thinking skills of PGSD students. Aspect Choosing the right font is an important element in ensuring readability and user comfort. A score of 4 indicates that the font types and sizes used in the modules are good, although there is still room for improvement to better align with accessibility standards. This is important because the readability of the text has a direct effect on students' ability to understand the material and make critical reflections. Similarly, the aspect of illustration of images and videos also received a good score which showed that the content of images and videos was generally relevant to the learning topic. The results of media validation show that SIPEJAR's microlearning has met excellent quality standards, especially in visual, audio, and interactivity aspects. However, some aspects such as the readability of the text and the integration of visual elements with the material can be further improved to optimize the effectiveness of learning. Overall, this validation supports the finding that SIPEJAR microlearning is a valid and relevant medium to empower the critical thinking skills of PGSD students.

Another factor that supports the achievement of this result is because students are given freedom or independence in their learning. Microlearning provides materials and several problems that students must solve on their own. This freedom stimulates students' creativity to analyze and critically analyze problems as part of critical thinking skills (Scott, 2015). After the problem is analyzed and criticized, students will plan to determine their own learning method or style (Conole, 2013; Harasim, 2012; Schunk, 2012).

In addition to presenting problems, SIPEJAR also directs student learning activities to study the material with their groups. This group activity provides an opportunity for students to collaborate with their ideas and mindsets with other students so that there will be a process of cognitive conflict that involves the process of analyzing, assessing, evaluating and making decisions (Asunka, 2017; Churchill et

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p-ISSN : 2303 - 355X I e-ISSN : 2685 - 2217
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al., 2016; Murphy & Farley, 2017; Stacey et al., 2017). Collaboration is inseparable from discussions where phenomenal learning activities develop cognitive skills and critical thinking skills (Anderson et al., 2017; Wu, 2019). According to Zheng (2017) and Yu et al., (2017) Collaboration and discussion can improve the flexibility of social interaction and critical thinking skills. In addition, through discussions, students develop their own concepts of knowledge (Koohang et al., 2009; Tavangarian et al., 2004).

The ability of prospective elementary school teacher students who are classified as Generation Z in accessing information from the internet is unquestionable. Collaboration and discussion activities carried out online are very complex activities because students collaborate ideas and ideas from discussions, collaborate on materials in SIPEJAR and the results of internet access. This causes students to experience a high level of cognitive conflict, especially involving the use of technology that is very effective in improving cognitive skills (Kintu et al., 2017; Pulla, 2017) dan literasi digital (Hunter, 2015). Learning activities like this teach students to think "out of the box" in learning something new (Anderson et al., 2017; N. Brouwer, P. J. Dekker, 2013).

While SIPEJAR has shown significant benefits for PGSD students, its modular design and adaptability suggest potential applications in other educational levels and disciplines. For instance, in secondary education, SIPEJAR could be tailored to subjects like science and mathematics by incorporating discipline-specific multimedia content. However, adapting the platform to these contexts may present challenges such as varying levels of technological access and differing curriculum needs.

Despite its promising findings, this study has limitations. The sample size of 76 students, while sufficient for statistical analysis, may not capture the full variability of the target population. Additionally, the study focused on a single institution, which may limit the generalizability of results. Validation processes, although thorough, could be subject to biases due to reliance on expert judgment. Future research should explore longitudinal impacts, scalability, and applications in diverse educational settings (Sipayung et al. 2020).

In closing, the results of this study affirm the importance of technology integration in 21st century learning, especially through the development of SIPEJAR-based microlearning. The findings show that this approach is not only valid in terms of media and content, but also effective in improving the critical thinking skills of PGSD students. The implementation of microlearning provides new opportunities for students to engage in learning that is more interactive, flexible, and relevant to the needs of the times. In addition, expert validation and empirical data analysis results show consistency between the applied learning design and the achievement of learning objectives. The advantage of SIPEJAR lies in the ability to present material in a modular and focused manner, thus allowing students to learn important concepts gradually without feeling overwhelmed. However, these findings also underscore the importance of continuous evaluation to improve certain aspects that are not yet optimal, such as increased integration between visual and textual elements, as well as enrichment of video context to make it more relevant to practical needs. The implications of this study are not only limited to the development of microlearning for PGSD students but can also be a reference for the development of learning technology at various other levels of education. Thus, this research makes a significant contribution to digital pedagogical innovation, as well as a foothold for further research that can explore the potential of technology-based learning in a deeper and broader way.

CONCLUSION

The conclusion of this study confirms that the development of SIPEJAR-based microlearning is a valid and effective approach in improving the critical thinking skills of students of the Elementary School Teacher Education Study Program (PGSD). Validation by media experts shows that the microlearning design has met high quality standards, with an emphasis on visual, audio, and intuitive layout aspects, all of which support an interactive and enjoyable learning experience. With an average validation score of 4.6 ("Very Good" classification), SIPEJAR microlearning has proven to have technical and pedagogical qualities that are relevant to the demands of learning in the digital era.

In terms of effectiveness, the results showed that students in the experimental class who used SIPEJAR significantly improved their critical thinking skills compared to students in the control class. This improvement can be seen in the ability of students to analyze, evaluate, and reflect on the learning concepts given. SIPEJAR's modular design, which incorporates multimedia elements such as videos, illustrations, and texts, provides flexibility for students to access materials independently and in-depth, thus supporting active and continuous learning.

This research makes an important contribution to technology-based learning innovation, especially in the context of teacher education. SIPEJAR microlearning is not only relevant for the development of critical thinking skills of PGSD students but can also be adapted to other levels of education with similar needs. However, the study also underscores the importance of continuous evaluation and development to ensure more optimal effectiveness in the future. Thus, SIPEJAR is not only a digital learning solution today, but also has the potential to become a broader pedagogical model to support technology-based education in the future.

ACKNOWLEDGMENT

Gratitude is expressed to the Universitas Negeri Malang, especially the Fakultas Ilmu Pendidikan, for the support and trust that has been given in the form of funding for this research through the Faculty Decentralization Grant scheme. This support not only allows the implementation of research that focuses on the development of SIPEJAR-based microlearning to empower the critical thinking skills of PGSD students, but also becomes a real step in encouraging technology-based learning innovation in the world of education. We hope that the results of this study can make a significant contribution to the development of education, both in the campus environment and on a wider scale.

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JURNAL EDUSCIENCE (JES)
p-ISSN : 2303 - 355X I e-ISSN : 2685 - 2217
PUBLISHED BY : LPPM of UNIVERSITAS LABUHANBATU

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