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Development of "LELI" Application to Enhance Mathematics Critical Thinking of Quality Generations in Society 5.0 Era

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Abstract

Students' mathematical critical thinking skills are one of the important competencies that need to be developed to face the challenges of the Society 5.0 era. However, conventional learning, which is less interactive, is often an obstacle to improving these abilities. This study aims to develop an interactive learning application called "LELI" to enhance junior high school students' mathematical critical thinking skills in the context of integer material. This type of research is a development approach utilizing the Research and Development (R&D) method in conjunction with the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model. The subjects of this study were grade VII junior high school students in the *Merdeka Curriculum*. Data collection techniques included observation, unstructured interviews, and tests. Data collection instruments used expert validation sheets, student response questionnaire sheets, and pre-tests and post-tests. The results showed that the "LELI" application was valid (77%), very practical (95.95%), and effective in improving critical thinking skills, with the average student score increasing from 65% (good) to 85% (very good). Based on the results obtained, the "LELI" application is valid, practical, and effective in improving the critical thinking skills of junior high school students in learning mathematics on integer material. These findings suggest that the "LELI" application can be a strategic solution for educators to enhance critical mathematical thinking skills in alignment with the demands of the Society 5.0 era.

Keywords: Critical Thinking; LELI Application; Interactive Learning.

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Abstrak

Kemampuan berpikir kritis matematis siswa menjadi salah satu kompetensi penting yang perlu dikembangkan untuk menghadapi tantangan era Society 5.0. Namun, pembelajaran konvensional yang kurang interaktif seringkali menjadi kendala dalam meningkatkan kemampuan tersebut. Penelitian ini bertujuan untuk mengembangkan aplikasi pembelajaran interaktif bernama "LELI" untuk meningkatkan kemampuan berpikir kritis matematis siswa SMP pada materi bilangan bulat. Jenis penelitian ini adalah pengembangan menggunakan metode Research and Development (R&D) dengan model ADDIE (Analysis, Design, Development, Implementation, Evaluation). Subjek penelitian ini adalah siswa kelas VII SMP pada kurikulum merdeka. Teknik pengumpulan data berupa observasi, wawancara secara tidak terstruktur, dan tes. Instrumen pengumpulan data menggunakan lembar validasi ahli, lembar angket respon siswa, serta pre-test dan post-test. Hasil menunjukkan aplikasi "LELI" valid (77%), sangat praktis (95,95%), dan efektif meningkatkan kemampuan berpikir kritis, dengan score rata-rata siswa meningkat dari 65% (baik) menjadi 85% (sangat baik). Berdasarkan hasil yang diperoleh, maka aplikasi "LELI" valid, praktis, dan efektif untuk meningkatkan kemampuan berpikir kritis siswa SMP pada pembelajaran matematika materi bilangan bulat. Temuan ini menunjukkan bahwa aplikasi "LELI" dapat menjadi solusi strategis bagi para pendidik untuk meningkatkan kemampuan berpikir kritis matematis yang sejalan dengan tuntutan era society 5.0.

INTRODUCTION

Education plays a pivotal role in improving the quality of life and elevating the standard of living, especially in preparing a competent young generation to support Indonesia's Golden Era 2045. To achieve this, integrating technology into the educational process becomes essential (Chugh et al., 2023). Consequently, education necessitates the integration of technology to augment the pedagogical process (Engelbrecht & Oates, 2022). Technological advancements in the era of Society 5.0 will have a significant impact on the realm of education. Society 5.0 not only emphasizes technological integration but also necessitates the transformation of educational models to accommodate personalized, data-driven, and interactive learning environments supported by IoT and AI technologies (Ghosh & Jermsittiparsert, 2024). The transition from Society 4.0 to Society 5.0 introduces a paradigm shift where technological sophistication is not the endpoint but rather a means to serve human needs more holistically. In this context, education must not only adapt by integrating digital tools but also empower students with higher-order thinking skills, such as critical thinking, creativity, and problem-solving (Vincent-Lancrin, 2023). Mathematics, being a discipline that trains logical reasoning and structured problem-solving, plays a pivotal role in preparing students for this era. However, as noted by Schlauch (2022), one of the pressing challenges is how to ensure that technology integration in math classrooms truly enhances students' conceptual understanding rather than just digitizing traditional methods.

Society 5.0 will be conceptualized with an extensive database, subsequently aggregated by the Internet of Things (IoT), which will then transform Artificial Intelligence (AI) into entities that can assist the community (Tavares et al., 2022). Society 5.0 represents a human-centric and technology-driven paradigm of society, thereby facilitating educational processes, including mathematical instruction (Hakeu et al., 2023)

The integration of digital technology into the learning process is crucial for creating more adaptive, efficient, and student-centered educational environments in the digital era. One of the key innovations supporting this transformation is the Internet of Things (IoT), which plays a significant role in overseeing and optimizing pedagogical activities. The presence of IoT can substantially contribute to advancements such as

smart cities, smart environments, smart governance, smart branding, smart living, and smart education (Y. Chen, 2022; Wan & Lin, 2022). In an educational context, the Internet of Things (IoT) refers to interconnected digital devices and systems that collect, exchange and analyze learning data to create a more responsive and adaptive learning experience (Machkour & Abriane, 2024). Radouan (2021) elucidates that the application of IoT can be constructed upon intricate architectures and diverse apparatuses and integrated into communicative frameworks. The Internet of Things (IoT) possesses the capacity to bolster the digital transformation of education in preparation for the era of Society 5.0 (Beng et al., 2022; Hsiao et al., 2023). The Internet of Things (IoT) has the potential to convert the educational paradigm into a dynamic, cooperative, and autonomous learning framework (Tavares et al., 2022). Furthermore, IoT can be articulated as having the capability to alter and impact the modalities of educational and instructional activities by furnishing students with quantifiable knowledge (Ghosh & Jermsittiparsert, 2024).

Critical thinking in mathematical education can cultivate learners to engage actively in the acquisition and exploration of novel concepts and significant experiences, thereby enabling students to become accustomed to confronting challenges and resolving problems proficiently (Vincent-Lancrin, 2023). In practical terms, however, students' mathematical critical thinking competencies are still categorized as deficient (Khotimah et al., 2023). This assertion is substantiated in Baiduri et al. (2023) research, which indicates that contemporary mathematical instruction is inadequately effective in motivating student engagement, consequently resulting in diminished critical thinking skills and poor academic performance among students.

Integers were selected as the initial content topic in this study due to their foundational role in middle school mathematics and the persistent difficulties students face when engaging with this material. Despite being introduced at an early stage, integer operations, especially those involving negative values, order of operations, and contextual problems, are often misunderstood by students, leading to conceptual confusion and computational errors. These difficulties stem not only from abstract representations but also from the inability to relate integer concepts to real-life situations. As reported by Khotimah et al. (2023) and Hervilia et al. (2023), students often struggle to distinguish directionality in values (e.g., loss vs. gain, elevation above or below zero) and apply integer rules consistently. Choosing integers as the topic aligns with enhancing critical thinking, as it requires learners to interpret contexts, analyze operations, justify solutions, and self-monitor their reasoning processes — all of which reflect core elements of critical mathematical thinking.

The *Merdeka Curriculum* in Indonesia emphasizes differentiated learning and the development of student skills, making critical thinking a central competency across subjects. In mathematics, this translates into designing learning experiences that are exploratory, contextual, and student-centered. Critical thinking should be cultivated not only at senior levels but also at early secondary levels to ensure continuity and cognitive maturity (R. Chen, 2024). Unfortunately, many junior high school classrooms still rely on procedural instruction, limiting

opportunities for students to engage in reflective thinking, open-ended reasoning, and self-evaluation (Mangarin & Caballes, 2024). This gap between curriculum intent and classroom practice necessitates innovative instructional solutions.

Based on preliminary observations and informal interviews with educators at a Junior High School, it was revealed that mathematical instruction employing didactic methods and predominantly emphasizing student assignments restricts opportunities for learners to cultivate their critical thinking abilities. This notion is further validated by Hervilia et al. (2023), who indicate that a majority of students in junior high school continue to encounter challenges in comprehending mathematical concepts, thereby leading to computational inaccuracies. This scenario limits students' opportunities to encounter stimulating learning experiences that foster the enhancement of their critical thinking proficiencies. The following CT skills were incorporated in all fifteen lessons: a clear search for a hypothesis or question, evaluation of reliable sources, identifying variables, "thinking out of the box," and searching for alternatives (Aizikovitsh & Amit, 2010).

The obstacles encountered in mathematical education, particularly the enhancement of critical thinking abilities, remain a considerable concern (Lee & Paul, 2023). Numerous learners experience challenges in comprehending the abstract principles of mathematics, which ultimately influences their diminished motivation to engage in learning (Mangarin & Caballes, 2024). To surmount these difficulties, innovation is needed in learning methods by utilizing technology, such as interactive learning applications. Interactive educational media, as conceptualized in this study, integrate digital tools and platforms to provide visual and auditory learning experiences that foster active engagement and higher-order thinking (Rajib Hossain, 2023). The "LELI" (Let's Learn Integers) application represents an innovative approach in the world of mathematics education, offering an effective method to enhance students' critical mathematical thinking skills and provide a more engaging and effective learning experience. This application is designed with interactive features that allow students to learn mathematics according to their respective learning styles. Through various activities, simulations, and challenging questions, "LELI" is expected to improve critical thinking skills in mathematics.

The development of the "LELI" application integrates several other applications to provide diversity in content presentation, including Google Sites, Wordwall, Canva, and Live Worksheets. The integration is executed to ensure that the developed application is not merely informative but also interactive and imaginative, thereby fostering learners' capacity for critical thought. The application encompasses numerous features, including educational materials, simulations, exemplar inquiries, interactive questions, discussions, and quizzes. The educational material features and example problems serve to assist learners in grasping the concept of resolving exemplar challenges about the content. Students can employ simulations, interactive exercises, and quizzes to develop logical reasoning, analyze information, devise innovative solutions, and solve mathematical problems. The integration of technological learning tools into curricula can be a way to develop critical thinking skills globally. In addition, interactive learning has the potential to significantly

impact mental abilities (Song & Cai, 2024).

Several research studies on critical thinking have been conducted, specifically focusing on the development of instruments and media that enhance critical thinking (Hidayati et al., 2024; Khotimah et al., 2023; Nurafifah et al., 2024). Khotimah et al. (2023) described a discovery of a learning-based device that is effective in improving critical thinking skills. In addition, Hidayati et al. (2024) and Nurafifah et al. (2024) found that learning using interactive media can increase students' activeness and critical thinking skills. Where interactive learning is student-oriented, student participation is more dominant than that of educators, allowing for feedback responses. This approach enables students to think critically about the issues discussed (Kusuma et al., 2022). Furthermore, Hartono & Sari (2023) and Permatasari et al. (2022) also applied learning models and strategies to improve critical thinking. However, no research has endeavored to correlate it with the development of interactive media in the context of the 5.0 societal era. The LELI application is an integration of innovative technologies to facilitate student-centered and interactive mathematics learning, which is in line with the core principles of Society 5.0, namely emphasizing technological innovations such as the Internet of Things (IoT) and Artificial Intelligence (AI) to create human-centered solutions, especially in education (Machkour & Abriane, 2024). Therefore, this research is worthwhile to conduct in order to develop a valid, practical, and effective "LELI" media that enhances the critical mathematical thinking skills of future generations in the era of Society 5.0.

METHOD

This category of research is advancement employing Research and Development (R&D) methodologies. The advancement framework utilized is ADDIE (Analysis, Design, Development, Implementation, Evaluation) (Hu, 2023). The ADDIE advancement framework is more suitable for the progression employed in enhancing a web-based or software-based pedagogical medium, as well as the systematic and comprehensible developmental phases utilized in the enhancement of an educational medium (et al., 2024). The product was formulated and subsequently assessed for its viability utilizing validity and trial-testing to ascertain the degree to which the application of "LELI" can augment students' critical reasoning abilities in integer content.

The selection of the ADDIE model in this study is based on its structured and iterative nature, which is particularly effective for developing technology-based instructional media (Aprilia et al., 2024). Each phase of the ADDIE framework supports systematic analysis and continuous improvement, allowing researchers to identify user needs, design targeted content, implement interactive features, and evaluate effectiveness through measurable outcomes (Hu, 2023). The flexibility of the ADDIE model also accommodates revisions based on formative feedback during development, making it suitable for media that require high usability, such as digital learning applications. Its emphasis on both instructional quality and learner experience aligns with the pedagogical goals of enhancing critical thinking skills in mathematics.

In the analytical phase, that is, scrutinizing the curriculum employed to comprehend the curriculum and the

pedagogical materials utilized, further examination of the content is conducted to ascertain the load that will be incorporated into the educational medium based on the syllabus of the Mathematic subjects on Integers. Subsequently, at the design phase, it is executed on the creation of research products and instruments. The formulation of the application design combines several applications to provide diversity in content delivery, including Google Sites, Wordwall, Canva, and Live Worksheets. The e-module design is tailored to pre-established content and authentic conditions to facilitate student acceptance. In the development phase, the pre-designed application is then deliberated with the supervising lecturer. Thereafter, it will undergo validation by content specialists and media experts. The outcomes of this validation are utilized to enhance the application, which is then trial-tested to ascertain its viability in improving students' mathematical critical reasoning capabilities. Ultimately, researchers conducted evaluations based on pre-test and post-test outcomes administered to students to assess the quality and viability of "LELI" applications, which were developed using a quantitative design.

This research was conducted at a junior high school in the VII grade, which took place in the even semester of the 2024/2025 academic year. The participants of the research were VII-A pupils comprising 24 individuals. Conversely, the focus of this research is the implementation of "LELI." Additionally, data collection methods included observation, unstructured interviews, and tests. The data collection instrument used in the research consisted of expert validation sheets, pre-tests, post-tests, and student response questionnaires. Expert validation questionnaires are directed toward evaluators from academic and professional backgrounds. Pre-test, post-test, and response questionnaires are directed toward students. In the media validation questionnaire, a Likert scale rating was employed, with the highest value being 5 (Strongly Agree) and the lowest being 1 (Strongly Disagree). The outcomes of the questionnaire are quantified in percentages and subsequently analyzed by the validation assessment criteria. Each dimension of the validation test questionnaire grid is scored based on the following guiding responses:

Table 1. Validation Assessment Criteria

Score (%)	Criteria
$80 < P \leq 100$	Very Valid
$60 < P \leq 80$	Valid
$40 < P \leq 60$	Sufficient
$20 < P \leq 40$	Less Valid
$P \leq 20$	Not Valid

Pragmatic analysis. This analysis is employed to assess the practicality of the application, which comprises four elements: usability, advantage, sustainability and coherence, and transparency in the instructional material. The scale used in the document is the Likert scale, employing the checklist methodology. The practicality criteria will subsequently exhibit the conclusive outcomes of the statements delineated below (Aprilia et al., 2024).

Table 2. Practicality Criteria

Score (%)	Criteria
$0 < \square \leq 20$	Very Impractical
$20 < \square \leq 40$	Not Practical
$40 < \square \leq 60$	Less Practical
$60 < \square \leq 80$	Practical
$80 < \square \leq 100$	Very Practical

The effectiveness analysis can be discerned from the outcomes of the learners' proficiency assessment concerning integer operations. These

assessments are conducted through pre-tests and post-tests, which are administered before and after the use of the "LELI" application. The purpose is to determine the improvement in students' mathematical critical thinking skills regarding integer material. The percentage score representing effectiveness is calculated using the formula:

$$Presentation\ Test = \frac{\sum Test\ Score}{Max\ Score} \times 100.$$

Based on the percentage calculation above, the pre-test and post-test results are then compared to determine whether there is an increase in student ability. The effectiveness assessment to evaluate product feasibility is described using the Likert scale as follows:

Table 3. Effectiveness Assessment Criteria

Score (%)	Criteria
$80 < P \leq 100$	Very Good
$60 < P \leq 80$	Good
$40 < P \leq 60$	Quite Good
$20 < P \leq 40$	Not Good
$P \leq 20$	Very Bad

The feedback questionnaire for pupils was administered to ascertain the applicability of the media. If the feedback results indicate a percentage greater than 60%, then the product is deemed applicable. The following formula computes the percentage of the questionnaire:

$$Persentation = \frac{Respondent\ Score}{Maximum\ Score} \times 100.$$

The data analysis methodology employed in this study is a quantitative descriptive approach, elucidating the outcomes of project-based e-module development (Rosyadi, 2023). Data acquired from respondents and validators were subsequently averaged to ascertain the quality and viability of implementing "LELI" to enhance students' mathematical critical thinking capabilities concerning integer material.

RESULT AND DISCUSSION

Results

This research employs the ADDIE developmental framework, which comprises five phases: analysis, design, development, implementation, and evaluation.

Analysis

The outcomes of the analysis, which advanced the "LELI" application, include a needs assessment, curriculum analysis, and media examination. A needs assessment is conducted through systematic observation at the educational institution to identify issues pertinent to the instructional process. The information acquired indicates: 1) Mathematical instruction predominantly utilizes assignment methodologies that hinder students' capacity to cultivate their cognitive abilities; 2) An insufficiency of interactive instructional media, resulting in diminished student motivation toward mathematical learning; 3) The pedagogical model employed is Problem-Based Learning (PBL), yet the challenges presented to students predominantly concentrate on comprehension dimensions, thereby inadequately fostering the enhancement of students' critical thinking competencies. Consequently, an interactive educational medium is requisite to assist students in refining their critical thinking capabilities.

Curriculum analysis, undertaken based on the Independent Curriculum that adheres to national curriculum benchmarks, adopts a learner-centered paradigm customized to their distinctive characteristics and requirements (Cholilah et al., 2023). The findings of this

evaluation reveal a lack of emphasis on the critical thinking dimensions of students, specifically the provision of higher-order reasoning inquiries that not only focus on procedural solutions but also encourage students to articulate their cognitive processes. Furthermore, conventional instructional practices tend to disrupt students' concentration during the mid-phase of learning. The implications of the analysis have a negative impact on students' mathematical critical thinking capabilities, particularly about integer concepts.

Media examination. Based on the conducted analysis, it is evident that the previously utilized instructional medium predominantly fixates on the facets of mathematical comprehension. Hence, the application "LELI" was developed to enhance students' critical thinking abilities.

Design

The subsequent phase involves formulating the product in the guise of the application medium "LELI". This application is meticulously crafted in alignment with the developmental objective of enhancing students' mathematical critical thinking capabilities. Such objectives are actualized through the comprehensiveness and lucidity of the materials and components encompassed therein. Pre-test and Post-test integer materials are integrated into the application interactively and innovatively to cultivate learners' critical thinking skills.

Media references. In the creation of the "LELI" application medium, researchers seek and amass references from a diverse array of sources. Reference media viewpoints and visuals are derived from Canva, materials from YouTube, and pedagogical modules from previous researchers. Additionally, there are media designs fabricated utilizing Canva. Upon completing the app's design, it is subsequently hosted on Google Sites to facilitate reaccessibility.

Media draft. The design is presented as a concise overview of the application's architecture. The architecture of this application comprises the following elements: 1) The introductory interface (Home). 2) The subsequent display is instructions for utilization. 3) Syllabus by the independent curriculum, which encompasses Learning Achievements, Learning Objectives, and the Flow of Learning Objectives. 4) The central interface consists of the material, Pre-test, and Post-test. The material is categorized into two segments, namely, the operations of integers and the properties of integers. 7) The evaluation interface (assignment), which is a quiz embodying indicators of critical thinking. 8) Profile of the stakeholders.

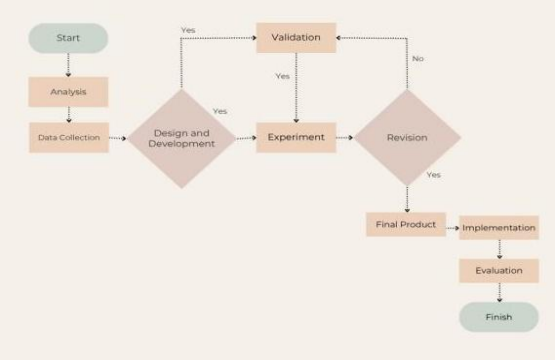

Figure 1. LELI Application Development Flowchart

Design of validation sheet instrument. The media validation sheet consists of material and media. Media validation includes aspects of material, construct, use, and design (appearance). Material validation encompasses aspects of material suitability, linguistic feasibility, presentation feasibility, and mathematical critical thinking. The media validation sheet grid is as follows.

Table 4. Validation Instrument Grid

Aspect and Indicator	Number of Question Items
Material	
Material (Content)	11
Use of Language	2
Presentment	5
Media	
Material (Content)	5
Construct	6
Appearance	11

Development

At this juncture, it is imperative to advance the application medium, "LELI," which corresponds to the design formulated during the design phase. The platforms utilized to construct e-modules are Canva and Google Sites.

Procedures in the application advancement phase begin with the researcher devising a visual layout for each component to be integrated into the medium. Subsequently, the file is incorporated into Google Sites to ensure it is accessible via the internet and adaptable for repeated use. Here is the application link "LELI" integer material: https://sites.google.com/view/medialeli-lets-learn-integers?usp=sharing

Following its development and manifestation as an application, it was then subjected to validation by two assessors: a lecturer in Mathematics Education at the University of Muhammadiyah Malang, serving as a media expert, and a mathematics educator from a Junior High School, acting as a content expert. The outcomes of the media evaluation conducted by the validators are presented in the subsequent table.

Table 5. Validator Assessment Result (P)

Aspect	Score	Max	P(%)	Criteria
Material	78	90	85	Very Valid
Media	76	110	69	Valid
	P Average		77	Valid

Table 5 illustrates an average proportion of 77% within the classification "Valid," thereby indicating that e-modules are deemed commendable and appropriate for utilization as instructional resources in mathematical pedagogy. The outcomes of the validity examination were substantiated by the research of (Aprilia et al., 2024), which revealed that at the phase of media validation, a percentage ranging from $60 < \square \leq 80$ was categorized as "Valid," thereby indicating that the application medium "LELI" is appropriate for utilization.

Following the validation procedure, the e-module is refined by the recommendations provided by the validator to produce an electronic educational module that is ready for implementation in pedagogical contexts. Subject matter experts recommend enhancing clarity in the instructions and providing elucidations in visual representations. Concurrently, media specialists advocate for the integration of interactive user interfaces and the inclusion of animations or videos to enhance the user experience. At the subsequent phase, following the acquisition of validation outcomes, it proceeds with the media revision stage.

Figure 2. Media Before Revision

Figure 3. Media After Revision

In enhancing the educational media after validation, the developers also incorporated several interactive icons to make it more engaging for the user. Subsequently, we included various exercises in the form of "assignments" based on the recommendations from subject matter experts.

Practicality analysis. This analysis was conducted based on a questionnaire, with students serving as respondents. The demographics of the respondents in this inquiry encompassed the clarity of instructions for utilization, lucidity of material discourse, coherence and preservation of media aesthetics and chromaticity, user-friendliness of the media, sustainability, and functionality of the media, advantages of the media, and whether it can augment learning motivation. In greater detail, this can be observed in the ensuing table.

Table 6. Avarage Score of Student Questionnaire

Statement	Score	*P* (%)	Criteria
1	113	94,16	Very Good
2	120	100	Very Good
3	114	95	Very Good
4	114	95	Very Good
5	114	95	Very Good
6	118	98,33	Very Good
7	113	94,16	Very Good
P Average =		95,95	Very Good

Information:
Maximum score = 120

Table 6 presents the mean percentage of the LELI application medium practicality score, with an average of 95.95% classified under the "Very Practical" criterion. Consequently, LELI applications can be asserted to be exceedingly practical for application in mathematical education.

Implementation

In the implementation phase, the LELI application medium was piloted directly on 24 class VII-A junior high school students. This implementation aims to evaluate the efficacy of "LELI" applications in enhancing students' mathematical critical thinking skills related to integer material. During the implementation process, students are permitted to select their preferred device; they may utilize either a mobile phone or a laptop.

The execution phase begins with a preliminary assessment, which is administered to gauge the learner's initial proficiency in mathematical critical reasoning related to integer content. The preliminary assessment comprises five narrative inquiries that evaluate critical thinking indicators, including interpretation, analysis, and appraisal. The narrative question contains a mathematical problem on the subject of numbers where students must be able to identify the mathematical problem, analyze information, evaluate arguments or discuss solutions when their friends have different solutions, and draw conclusions and develop alternative solutions to solve the question. The outcomes of the preliminary assessment will serve as a benchmark for comparison with the subsequent assessment following the implementation of the LELI application medium.

Following the preliminary assessment, learners are allowed to use the LELI application during educational activities. The application is structured to include features such as interactive content, simulation of integer concepts,

narrative inquiries, gamification-based quizzes, and automated scoring mechanisms. Learners dedicated an average of 15 minutes to complete the quiz, indicating active involvement during the learning process. Upon completion of the quiz, learners can autonomously assess their responses through the discourse provided within the application.

The final phase of implementation is the subsequent assessment. The subsequent assessment employs the identical inquiries as the preliminary assessment to ensure uniformity in results. The outcomes of the subsequent assessment are then juxtaposed with the results of the learners' preliminary assessment prior to using the LELI application medium. Should there be an enhancement in both assessments, it signifies that the LELI application has effectively exerted a beneficial influence on the development of learners' critical thinking competencies, particularly about integer content.

Evaluation

The culminating phase in the advancement of LELI application media is the evaluation aimed at enhancing learners' mathematical critical thinking capabilities concerning integer material.

Analysis of the outcomes of the preliminary assessment. This analysis was conducted to assess learners' initial proficiency in mathematical critical reasoning related to integer content. There are also preliminary assessment inquiries encompassing critical thinking stimulants with the ensuing results.

Figure 4. Pre-Test Critical Thinking of Evaluation

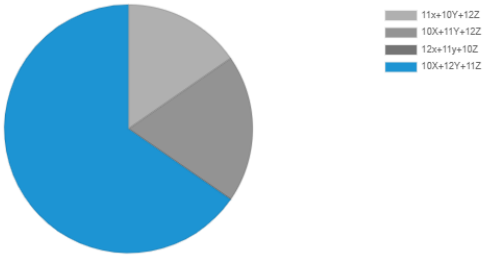

Figure 5. Post-Test Critical Thinking of Evaluation

The first part contains critical thinking indicators that evaluate points where students assess the situation as a whole, evaluate and filter information from two situations (initial and additional data), and then apply the weight of the assessment to obtain the final result in a logical and detailed manner. The blue part shows the number of students' correct answers. Based on the two figures, the post-test results indicate that the number of correct answers is higher than in the pre-test results.

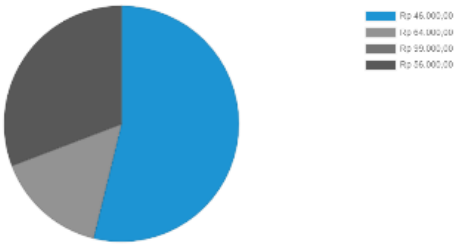

Figure 6. Pre-Test Critical Thinking of Self-Regulation

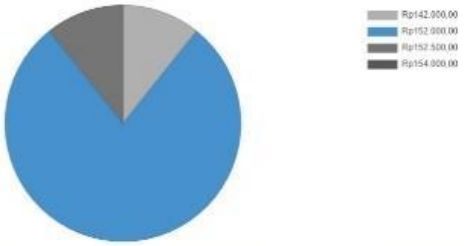

Figure 7. Post-Test Critical Thinking of Self-Regulation

The second part contains critical thinking indicators of self-regulation points, where students can double-check answers, correct mistakes, and ensure the accuracy of the results obtained. Starting from calculating the total expenditure of 14 days, then subtracting it from the initial money. This process demonstrates the ability to manage information, create a calculation plan, and verify the final result. The blue part shows the number of students' correct answers. Based on the two figures, the post-test results indicate that the number of correct answers is higher than in the pre-test results.

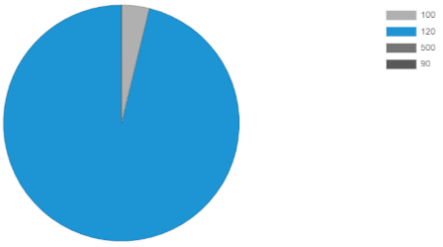

Figure 8. Pre-Test Critical Thinking of Interpretation

Figure 9. Post-Test Critical Thinking of Interpretation

The third part contains critical thinking indicators and interpretation points where learners can interpret mathematical symbols and number operation rules, as well as understand the order of arithmetic operations (mathematical rules), particularly the order of operations (multiplication before addition). This question assesses the ability to understand the meaning of numerical expressions so it can be concluded that learners can interpret symbols and operations in the right context. The blue part shows the number of students' correct answers. Based on the two figures, the graph shows that the number of correct answers from the pre-test and post-test results are equal, indicating that students understand the indicators of interpretation questions.

Figure 10. Pre-Test Critical Thinking of Explanation or Argument

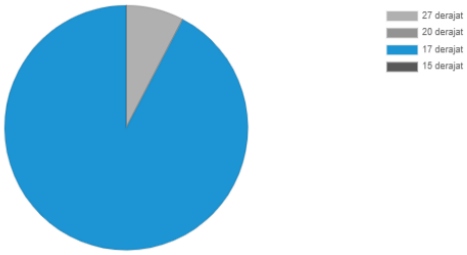

Figure 11. Post-Test Critical Thinking to Analyze

The fourth part contains critical thinking indicators of explanation or argument points, where students can clearly and logically state the mathematical process. Then, students are able to state the results or solutions of integer problems and describe the reasons behind the solution steps used, especially in the context of real-world problems. Have the ability to explain, especially in the rules of signs and powers. The blue part shows the number of students' correct answers. Based on the two figures, the post-test results indicate that the number of correct answers is higher than in the pre-test results.

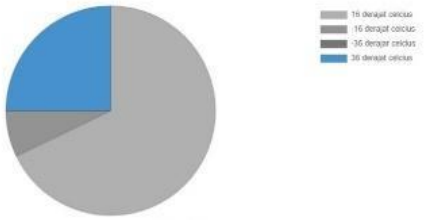

Figure 12. Pre-Test Critical Thinking to Analyze

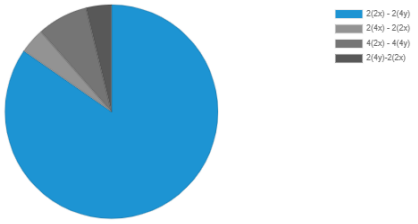

Figure 13. Post-Test Critical Thinking of Analyze

The fifth section contains critical thinking indicators of analysis points, where learners can analyze algebraic structures, identify the properties used (distributive and associative), and describe them to change the form of mathematical expressions. In addition, learners can also analyze situations involving two temperature data points and calculate the difference between two numbers with different signs (positive and negative). The problem requires recognizing integer patterns and the distance between values. The blue section shows the number of students' correct answers. Based on the two figures, the post-test results indicate that the number of correct answers is higher than in the pre-test results.

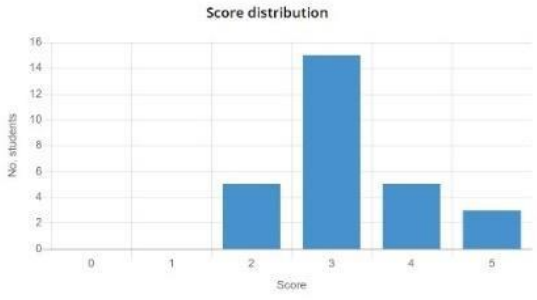

Figure 14. Pre-Test Result Score

The findings indicated that the mean scholar attained an accurate score of 3 out of a total of 5 inquiries, corresponding to a percentage of 65%, thus achieving a "Good" classification based on the Likert scale. From the illustration, it is evident that a considerable number of scholars achieved a correct score of 2 out of 5 inquiries. The sole individuals who responded accurately were merely three scholars. Based on the observations, the majority of scholars encountered challenges in comprehending the narrative, discerning salient information, and formulating logical arguments. The challenges substantiate the need for a more interactive pedagogical approach to help scholars enhance their critical thinking competencies.

Post-test analysis. This examination was conducted to evaluate the improvement in critical thinking capabilities following the scholars' use of the application. To assess the efficacy of LELI application media development, post-test result data will be juxtaposed with pre-assessment scores.

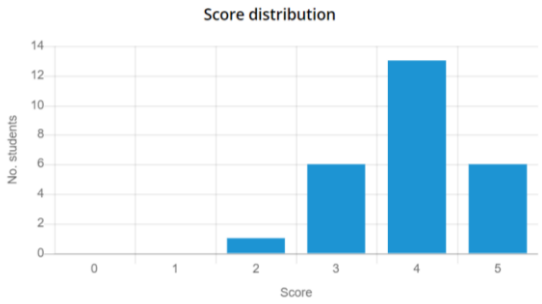

Figure 15. Post-Test Result Score

Figure 15 illustrates the outcomes of post-test evaluations, showing that the average student achieved a correct score of 4 out of 5 questions. The outcome corresponds to a percentage of 85% with a "Very Good" designation based on the Likert scale. Learners demonstrate substantial improvements in their ability to interpret information, analyze data, and evaluate solutions. In comparison to the pre-test, these findings substantiate that the implementation of "LELI" is effective in facilitating students' development of

mathematical critical thinking competencies, particularly about integer concepts.

Discussion

The research devised an educational medium in the format of "LELI" applications utilizing Google Sites. The selection of Google Sites as the principal platform for media development is attributable to its numerous advantages that bolster a successful execution. Google Sites enables the creation of user-centric web-based applications that are accessible on a multitude of devices (smartphones, tablets, laptops, or PCs) and do not require additional expenses (Engelbrecht & Oates, 2022). The platform further supports integration with various auxiliary applications, such as Wordwall for interactive assessments and Canva for visual design, resulting in applications that are not only informative but also interactive and engaging. Furthermore, Google Sites' capability to provide content updates in a swift and real-time manner empowers developers to tailor applications to meet student requirements and user feedback (Lee & Paul, 2023).

The "LELI" application is designed with interactive features, including simulations, narrative inquiries, and quizzes, that encourage active learning for students. These attributes align with the principle of Society 5.0, which accentuates the amalgamation of technology to enhance student-centered education. Interactive components within the application have been demonstrated to elevate student motivation, as corroborated by survey outcomes indicating that 94.16% of students expressed interest and motivation to engage with the application. These revelations are congruent with prior research indicating that interactive media can enhance student engagement and comprehension of abstract mathematical concepts (Schlauch, 2022).

The interactive quiz functionalities within the "LELI" application fulfill a critical role in fostering student engagement throughout the educational process. The findings revealed that the average student dedicated 15 to 20 minutes to completing the quiz. Elements such as points, levels, and challenges create an enjoyable educational experience, thereby enhancing students' motivation for independent learning (Ratinho & Martins, 2023). Consequently, this illustrates that the application successfully establishes a competitive yet constructive learning environment.

Students' critical thinking proficiency is assessed through indicators, namely their ability to identify and analyze questions, infer, and provide clear and logical explanations. The comparison of pre-test to post-test scores revealed an increment of 20%, with an initial score of 65% rising to 85%. Students who previously encountered challenges in comprehending narratives and identifying information in the pre-test subsequently demonstrated the ability to evaluate solutions and formulate logical arguments in the post-test.

The increase in students' post-test scores from an average of 65% to 85% can be attributed to the structured interaction facilitated by the LELI application. Through its features, such as gamified quizzes, narrative-based problems, and concept simulations, students were engaged in a learning process that actively required them to interpret mathematical situations, analyze information, justify reasoning, and reflect on their understanding. This finding aligns with Bruner's theory of discovery learning, which emphasizes that meaningful learning occurs when learners are

encouraged to explore and construct their knowledge (Bruner, 1961). Additionally, Vygotsky's social constructivist perspective supports the notion that interaction with instructional tools can serve as a scaffold, enabling students to perform tasks they might not be able to achieve independently (Vygotsky, 1978). The LELI application served as this scaffold by providing immediate feedback, visual representation, and challenge-based tasks. In the context of real classroom implementation, these findings suggest that thoughtfully designed digital media can significantly enhance critical thinking, particularly in abstract topics such as integers, which often pose conceptual difficulties for junior high school students.

The development of the "LELI" application revealed a significant improvement in mathematical problems. Initially, many struggled to interpret narrative problems and distinguish relevant information. After using the application, students demonstrated more systematic thinking, accurately identifying key data, evaluating their solutions, and drawing logical conclusions. This improvement aligns with Kaban et al. (2023), who found that the use of interactive learning media can significantly enhance students' analytical skills, problem-solving abilities, and engagement with mathematical concepts. This research indicates that the application "LELI" effectively cultivates students not only to comprehend the material but also to develop more effective problem-solving strategies.

Overall, the outcomes of this inquiry confirm the importance of technological advancements in mathematical education in equipping the younger generation for the challenges of the Society 5.0 era. By combining technology and student-centric pedagogical strategies, the "LELI" application not only enhances students' critical thinking capabilities but also promotes interactive learning. The use of platforms like Google Sites creates opportunities for the development of analogous applications that are effective, efficient, and readily accessible.

Implication of Research

The findings of this research carry several implications for various stakeholders. For future researchers, the development of the "LELI" application presents opportunities to conduct further studies on the integration of interactive media across diverse mathematical topics or with larger and more diverse student populations. For educational practitioners, this research offers a practical guide to adopting and adapting interactive, gamified learning applications that are student-centered and aligned with the Merdeka Curriculum. Meanwhile, for school administrators and policymakers, the success of this study highlights the importance of supporting digital innovation in classrooms. Thus, the implementation of applications like "LELI" can serve as a strategic step in realizing the goals of education in the Society 5.0 era, which emphasizes the synergy between student-centered learning and technological advancement.

Limitation

The constraints of the study reside in the restricted access to electronic devices for certain students and the limited instructional time within the classroom. Some students are hindered by Internet access when they attempt to use their electronic devices; thus, a plausible solution would be to collaborate with their peers. This study is also constrained and cannot be generalized broadly as it encompasses only 7th graders from a

singular institution, thereby necessitating further research involving a greater number of schools and grade levels to generalize the findings to a more extensive population.

CONCLUSION

Based on the outcomes of the research's analytical process, it can be inferred that the developed LELI application enhances students' mathematical critical thinking skills. The LELI applications concerning integer materials satisfy validity criteria with an average percentage attained from validators of 77%, meeting the "Valid" criteria and meeting practicality criteria from student response questionnaires of 95.95%, categorizing them under the "Very Practical" criteria. Project-based e-modules also enhance the student's mathematical critical thinking skills, achieving the "Very Good" criterion with an initial score of 65%, which then escalates to 85%. Based on the results obtained, the "LELI" application is valid, practical, and effective in improving the critical thinking skills of junior high school students in learning mathematics on integer material.

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