



ASIAN JOURNAL OF INTERDISCIPLINARY RESEARCH



Development and Evaluation of Computational Thinking Based Mathematics E-Comics for Enhancing Numeracy Skills in Junior High School Students

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DOI: <https://doi.org/10.54392/ajir2622>

Received: 30-09-2025; Revised: 18-03-2026; Accepted: 28-03-2026; Published: 20-04-2026



Abstract: Numeracy skills are needed to understand, apply, interpret, and solve contextual and complex problems. This is necessary because the process of solving problems in mathematics requires computational thinking steps. Therefore, this research aims to produce computational thinking-based e-comics to improve numeracy skills with a focus on students in grade VII of Junior High School. A research and development (R&D) design with the ADDIE model consisting of various stages such as analysis, design, development, implementation, and evaluation was applied. The research population is seventh grade junior high school students and the sample used is two classes of seventh grade, each totaling 32 people. The evaluation stage applied a quantitative approach with a quasi-experimental design. One class as an experimental class implementing computational thinking-based e-comics learning while the other class as a control class with interactive PowerPoint-assisted learning. The data collection methods used include interviews, student needs analysis questionnaires, validation and response questionnaires, numeracy test questions, and documentation. Moreover, the descriptive data retrieved from material and media experts were validated through validation sheets. Practicality analysis is also applied to teacher and student responses to the questionnaire sheets. The effectiveness analysis applies statistical procedures for normality tests, homogeneity, and statistical covariance analysis tests (ANCOVA). The results of expert validation showed an average of 84.79% which was categorized as valid. The practicality test also produced an average of 83% for the responses of the teachers and students which was classified as practical. Furthermore, the data showed normal and homogeneous categories. The ANCOVA test showed a significance value of $0.000 < 0.05$. The research findings prove that the developed computational thinking-based e-comics effectively had a positive effect on improving students' numeracy skills. The research findings provide implications for innovation in enjoyable learning processes and teacher professional development.

Keywords: Computational Thinking, Digital Learning Media, Educational Comics, Instructional Design, Mathematics Education, Numeracy Development.

1. Introduction

Mathematics is the underlying foundation for solving problems in several fields of science and has an important role in advancing science and technology (Maharani *et al.*, 2019). However, students often have difficulties with mathematics because the object of study is abstract. This problem has led to low mathematics learning achievement in Indonesia (Ariani, 2024; Helsa *et al.*, 2023). The trend was observed in the PISA report, which ranked Indonesia in 68th position out of 82 participating countries (Ahn, 2024). This shows the need for collective efforts to improve mathematical skills in solving contextual problems (Gholami, 2023; Tanujaya *et al.*, 2021).



The process of learning mathematics has experienced several changes due to the advancement of existing technology. This is observed from the need for students to optimally use technology based on computational thinking (CT) after possessing the skills to read, write, and count. CT is explained as the skills of students to think creatively, critically, and analytically in solving daily life problems (Mulyono, *et al.*, 2024). It is also defined as the method of reinforcing the problem-solving skills of the students (Wang *et al.*, 2022). The importance of the concept in mathematics learning cannot be underestimated because of the assistance in ensuring students understand mathematical concepts as well as experience an increase in creativity and critical thinking (Mulyono, *et al.*, 2024).

CT focuses on the skills to solve problems by utilizing concepts related to computing. The application is based on five indicators which include abstraction, representation, algorithm, decomposition, and evaluation (Gunawan *et al.*, 2024). The abstract thinking indicator is the skills to deduce a mathematical concept (Kallia *et al.*, 2021). Representation is defined as the capacity to present problems in a simple and easy-to-understand form (Utomo & Syarifah, 2021). Meanwhile, algorithms are a process of finding detailed solutions to problems and decomposition is the skills to break down large problems into smaller, different parts (Shute *et al.*, 2017). Evaluation is also explained as the skills to draw conclusions or final interpretations (Wu *et al.*, 2024).

CT is part of the key elements used in the development of numeracy skills (Lee *et al.*, 2024; Yang *et al.*, 2026; Zhang & Gary, 2023). It is because CT offers contextual problems as an alternative during the process of enhancing numeracy skills (Pratiwi *et al.*, 2024). Numeracy skills are defined as the ability to identify information, design solution strategies, implement solution steps, and interpret mathematical concepts or procedures in the context of problem solving (Nortvedt & Wiese, 2020). In the process of solving numeracy problems, it involves a CT process (Kaup, 2024; Wu & Yang, 2022). The CT process is connected in encouraging the development of numeracy skills. For example, the abstraction and representation indicators are connected to the numeracy indicator presenting the problem, the decomposition indicator is connected by communicating information, and the algorithm and evaluation indicators are connected with the numeracy indicator applying the solution. The trend is connected with the issue that the development of numeracy depends on the combination of both external and internal factors. One of the external factors is quality learning resources that are determined by the avail skills of good teaching materials as well as interactive media (Wuryani *et al.*, 2018). This is informed by the fact that the choice of suitable media is likely to be pegged on the capacity to facilitate student participation and meaningful learning experiences. One of the examples of the innovative media to enhance the quality of learning, particularly numeracy, is comics that are in demand in various spheres of life at the moment.

Comics are well-known artworks, particularly among children, and are frequently applied as instructional resources (Şahin & Kara, 2022; Özdemir, 2017). It is assumed that students are more interested in comics as opposed to textbooks (Akcanca, 2020). This is founded on the fact that it is usually a source of happiness and entertainment due to the lightness of the stories and communicative images (Matuk *et al.*, 2021; Ntobuo *et al.*, 2018). In addition, comics can be used to enhance literacy by providing more contextual stories to enhance the imagination skills of the students (Saputri & Qohar, 2020). It can also be used to increase interest and active engagement in the learning process (McGeown *et al.*, 2016; Toh *et al.*, 2017). The trend is linked with the potentiality of gaining enjoyable and significant learning via use of comics.

The fast advancement of technology and science is transforming the way of teaching in the education sector like the field of mathematics. This can be noted through the incorporation of information technology in learning as one of the strategic plans introduced in Education 4.0 (Miranda *et al.*, 2021). The modern digital world demands the implementation of the technology-based learning media to guarantee a greater number of interactions (Hidayat *et al.*, 2022; Hidayat *et al.*, 2023). One such media is the digital version of the comics known as e-comics that can support other learning materials, support conducive learning environment, and serve as a medium of literacy both in and out of the classroom (Berger *et al.*, 2023). E-comics usage can assist to enhance the skill of students to comprehend the context of the problem associated with everyday life (Yulaichah *et al.*, 2024). It can also contribute to the development of numeracy skills, help the teachers improve learning outcomes, as well as train critical thinking and creativity (Yulaichah *et al.*, 2024; Berger *et al.*, 2023).

Theoretically, the effectiveness of computational thinking-based e-comics (CT) in improving numeracy can be explained through the direct relationship between media design features and students' cognitive processes. Various studies show that CT in mathematics learning operates through core processes such as representation,



decomposition, abstraction, algorithms, and evaluations that directly support the solving of numeracy problems (Chan *et al.*, 2021; Lv *et al.*, 2023; Barcelos *et al.*, 2018). In the context of e-comics, visual and multimodal narratives (images, texts, dialogues) serve as representational tools that clarify abstract mathematical concepts into concrete and cognitively easy to process. These visual representations help students build more stable mental models, as it is emphasized that dynamic representations in learning technologies can strengthen understanding of mathematical concepts and relationships (Cui *et al.*, 2023).

Furthermore, the problem-based story structure in e-comics systematically encourages problem decomposition, where students are invited to solve complex problems into smaller, simpler pieces. Once the problem has been described, interactive features such as the choice of solution steps or story branching facilitate the selection of strategies (algorithmic thinking), i.e. students determine the logical sequence of steps to achieve the solution. Research shows that these algorithmic activities strengthen procedural reasoning and systematic thinking skills in mathematics (Luo *et al.*, 2022; Kong & Wang, 2021). The direct feedback mechanism in e-comics plays an important role in the process of evaluating and checking errors (debugging). When students receive responses to answers in the form of explanations, corrections, and instructions, they will be encouraged to revise strategies and correct mistakes independently. This evaluative process is a key component in CT that is closely related to the improvement of the accuracy and flexibility of numerical thinking (Dagiene & Dolgopolas, 2022).

E-comics innovation has been examined by previous scholars such as the comparison of the use of mathematical e-comics between Indonesia and Spanish students by (Marhaeni *et al.*, 2024). The results showed that Indonesian students were more curious about the use of e-comics compared to the Spanish and the learning medium also supported the development of digital literacy. The e-comics innovation based on ethnomathematics developed by Rahmasantika and Prahmana (2022) in the folklore context also enhanced the critical thinking abilities of students with special needs through the medium. Moreover, Hartati *et al.* (2023) created e-comics among deaf students and the results showed that the literacy skills improved relating to contextual problems. To achieve validity and practicality, Harisman *et al.* (2023) also created mathematical e-comics that integrated West Sumatra local wisdom. The e-comics was developed through the application of protons and electrons. The results showed an improvement in the skills of students with special needs to understand mathematical concepts. Johar *et al.* (2023) developed mathematics comics for students in rural and urban areas. The results showed that those in urban areas had better mathematical logical intelligence after using the medium compared to the rural area. Furthermore, Lestari *et al.* (2021) also designed mathematical comics based on Pancasila values which led to high critical thinking skills as well as the skills to develop disciplined and unyielding characters.

The previous research explanation only integrated contextual problems in the form of cultural values and local wisdom in comics but did not discuss and apply the cognitive thinking process in its content as part of strengthening conceptual understanding of mathematics and fun learning. The innovation of the CT stage has not been used as the basis for mathematical e-comics to improve computational skills in solving contextual problems. The comic raises contextual issues related to positive characters, then the completion process is arranged according to the stages of the CT process starting from abstraction, representation, decomposition, algorithms, and evaluations presented in the form of conversations between comic characters.

The presentation of the CT process provides reinforcement of students' conceptual and mathematical thinking in solving complex problems. This innovative CT e-comic product is part of the deep learning process with each character, comic visualization, content, problem context, and thought process integrated with deep learning aspects, namely mindfull, meaningfull, and joyfull. The collaboration between CT and e-comics has the potential to be an innovative solution to improve numeracy skills. The CT thinking process in comics is able to provide influence and habituation in the mathematical thinking process, especially numeracy steps. The use of various characters in this comic can also support the development of several affective aspects, especially those related to the values of Pancasila. This condition is information about the novelty of this research with previous research.

The differences identified led to the conduct of this research to develop CT-based e-comics that could satisfy the validity and practical aspects. There was also the need to determine the effectiveness of the CT-based e-comics in improving the numeracy skills of students. Therefore, the research question was formulated as "Are computational thinking-based e-comics valid, practical, and effective in improving the numeracy skills of junior high school students?".



2. Method

2.1 Research Design

A quantitative method with a quasi-experimental design approach was used to investigate the effectiveness of CT-based e-comics on numeracy skills. This is achieved through the Research and Development (R&D) method with the ADDIE model which is based on five stages, including analysis, design, development, implementation, and evaluation (Crompton *et al.*, 2024).

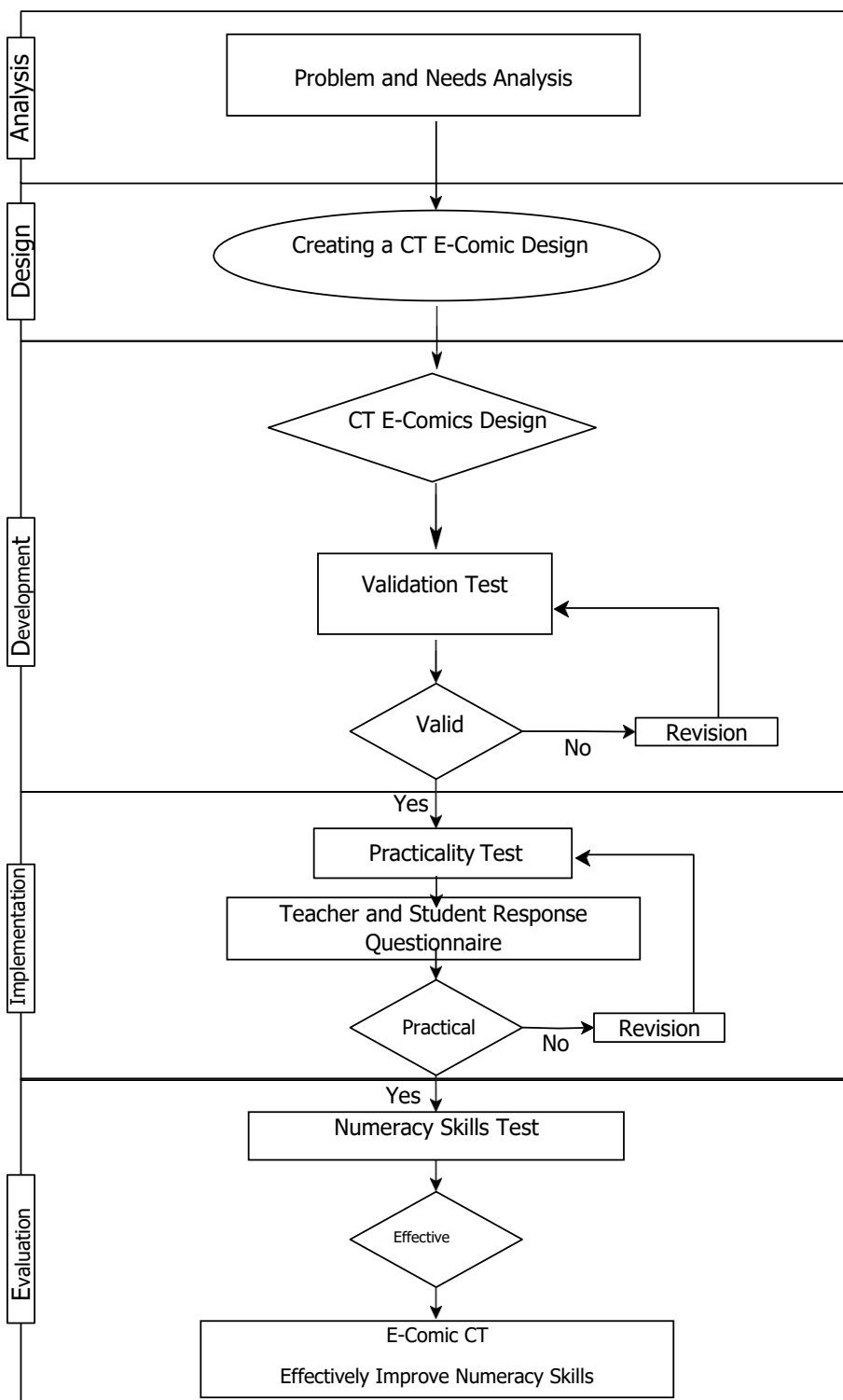


Figure 1. Research Design



Table 1. CT Framework

Components	Indicator CT				
	Abstraction	Representation	Decomposition	Algorithm	Evaluation
Learning Objectives	Identify important information and eliminate irrelevant.	Presenting problems in various forms (visual, symbolic, numerical)	Breaking down complex problems in a story into simple parts	Devise systematic steps to solve problems	Assess the correctness of the solution and correct the error
Comic Features	The characters begin to simplify the problem: 1. Turning a story into a mathematical form 2. Define variables	Figures use: 1. Table 2. Graphics 3. Diagram 4. Equations	1. Characters face contextual problems 2. The problem is broken down into parts: a. What is known? b. What is asked? c. What additional information is needed?	The figure compiles steps 1, step 2, and step 3	Figures check the results: 1. Does it make sense? 2. Is there a mistake?
Learning Activities	1. Observing contextual problem 2. Select relevant information 3. Create a mathematical model 4. Generalizing patterns	1. Change the shape of the representation 2. Interpreting charts/tables 3. Create a visual model	1. Identify the problem section 2. Write down sub-issues 3. Groups information	1. Compiling a logical sequence of steps 2. Using the correct procedure 3. Developing a settlement strategy	1. Verify results 2. Find errors 3. Revise the solution
Targeted Numeracy Proficiency Indicators	Presenting information	Presenting information	Communicating information	Implement solutions	1. Communicating information 2. Implement solutions

The first stage focused on the analysis of the problem and needs. Problem analysis was used to determine the challenges encountered by grade VII mathematics teachers during the learning process through interviews. The needs were also analyzed through a questionnaire filled out by the teachers.

The second stage was used to design the CT-based e-comics concept based on the results of the previous analysis. This was achieved through a comprehensive recording with due consideration for the design and material. The e-comics medium was produced using the Canva application while the comic characters were designed through Sketchbook. These were based on a comic story which emphasized on practice and sample questions as well as materials. The next step was the design of the product with a focus on the theme, cover, characters, and script plot making followed by the CT-based completion steps and numeracy test questions.

The third stage was to develop CT-based e-comics ready for implementation based on the design made. However, there was a need to determine the validity of the product before the implementation. This was conducted by validators who were media and subject matter experts. The product was subsequently refined according to feedback or suggestions provided. Moreover, the fourth stage was the implementation of the CT-based e-comics developed after appropriate refinement to ensure perfection. The product was tested on a limited trial basis in one class of 32 students and 1 classroom teacher. The criterion was to consider the product practice when the responses from the teacher and students were classified as good categories.



The final stage is an evaluation used to assess the effectiveness of CT-based electronic comics in improving numeracy skills. The application of CT e-comic learning was carried out in the experimental class while the learning in the control class used interactive power point media. The flow of the stages used in this research is presented in the following Figure 1. CT e-comic products are arranged according to the computational thinking component consisting of abstraction, representation, decomposition, algorithm, and evaluation. This product was developed to improve students' numeracy skills. Table 1 follows the CT framework for numeracy skills indicators.

Learning interventions using e-comics are designed in the form of problem-based narratives consisting of orientation, conflict, exploration, resolution, and reflection stages. In the initial stage, students are introduced to the context of a contextual story, then faced with a mathematical problem that must be solved through computational thinking process consisting of abstraction, representation, decomposition, algorithms, and evaluation. Students' interaction with e-comics is not passive, but active through activities such as navigating panels, answering interactive questions, choosing a solution strategy, and exploring available hints. During this process, students tend to read non-linearly at a certain point to think, try solutions, discuss with friends, and then resume the story.

2.2 Participants

The research sample consisted of 64 students in grade VII of Junior High School with the majority, 68.75%, found to be female. The age varied from 7.8125% who were less than 12 years old to 92.1875% who were between 12-13 years old and the religion embraced by all the students was Islam. It was observed that 39.0625% had less initial academic abilities but most students represented by 96.875% had Android devices and more than 50% possessed good information technology (IT) skills. Moreover, the sample was dominated by students from public elementary schools with 84.375%. The specific data on the personalities of the participants are presented in the following Table 2.

Table 2. Participants profile (N = 64)

Criteria	Number	Percentage (%)
Gender		
Male	20	31.25
Female	44	68.75
Age		
< 12 years	5	7.8125
12-13 years	59	92.1875
Religion		
Islam	64	100
Christian	0	0
Buddhism	0	0
Initial Academic Abilities		
Less	25	39.0625
Enough	20	31.25
Good	12	18.75
Very Good	7	10.9375
IT Skills		
Less	10	15.625
Enough	15	23.4375
Good	35	54.6875
Very Good	4	6.25
Gadget Ownership		
Personal	62	96.875
Parents	2	3.125
Elementary School Educational Background		
State	54	84.375
Private	10	15.625



At the needs analysis stage, the researcher involved mathematics teachers who taught in the class used as research and 32 students in grade VII A. The trial stage was limited to small groups involving students in different classes VII C of 32 students. The effectiveness testing stage was carried out in two different classes, namely classes VII A and VII C with a total of 32 students each. Class VII A is an experimental class and class VII C is a control class. Learning in the experimental class applied CT e-comics with a problem-based learning model. The control class applied a problem-based learning model assisted by interactive power point media. Sampling of classes VII A and VII C was carried out using cluster random sampling techniques.

2.3 Data Collection

The research instruments used consisted of interview guidelines, validation sheets, practicality questionnaires, and numeracy skills tests. The numeracy skills test is made based on the One Variable Linear Equation and Inequality System material which consists of three different questions. Each question is arranged according to the indicators of numeracy skills, namely presenting information, communicating information, and implementing solutions. The numeracy test questions adopt a description question type. The assessment was carried out according to the numeracy skills indicator starting from a score of 0-5. The maximum score of the three questions is 60. After the assessment of the answer score, the final score obtained is then calculated with the formula:

$$\text{Final numeracy score} = \frac{\text{score}}{\text{maximum score}} \times 100$$

The interviews were conducted with the classroom teacher for the purpose of the initial analysis and determination of needs. The validation sheets were grouped into two with a focus on the media and material, and subsequently distributed to validators to determine the validity of the CT-based e-comics developed. Response questionnaires were also provided to teachers and students to test the practicality. The response questionnaire consists of 18 statement items describing aspects of product display design, language, visualization, and usefulness. The assessment of each statement item uses a Likert scale of 1-4 (1: disagree, 1: disagree, 3: agree, and 4: strongly agree). Furthermore, numeracy tests were conducted on students before and after the trials using the CT-based e-comics developed in order to determine the effectiveness of the product.

Before the numeracy test instrument and student response questionnaire are given, a validity and reliability test is first carried out. The validation procedure was carried out by two experts in the field of learning evaluation and the field of mathematics learning media. The results of the validation of the numeracy test and questionnaire were analyzed using SPSS software. The following table 3 shows the results of the validity and reliability of the instrument.

Table 3. Recapitulation of the results of the validity and reliability test analysis

Aspects	Numeracy Test Questions			Students Response Questionnaires	Category
	Question 1	Question 2	Question 3		
Validation Test	<ul style="list-style-type: none"> • $R_{\text{count}} = 0.705 > r_{\text{table}} = 0.349$ • Sig. (2-tailed) = $0.000 < 0.05$ 	<ul style="list-style-type: none"> • $R_{\text{count}} = 0.415 > r_{\text{table}} = 0.349$ • Sig. (2-tailed) = $0.03 < 0.05$ 	<ul style="list-style-type: none"> • $R_{\text{count}} = 0.541 > r_{\text{table}} = 0.349$ • Sig. (2-tailed) = $0.002 < 0.05$ 	<ul style="list-style-type: none"> • $R_{\text{count}} = 0.517 > r_{\text{table}} = 0.349$ • Sig. (2-tailed) = $0.011 < 0.05$ 	Valid
Reliability Test	Cronbach Alpha Values = $0.711 > 0.70$			Cronbach Alpha Values = $0.801 > 0.70$	Reliable

The student response questionnaire and numeracy test are declared valid if the r-count value is greater than the r-table and the significance value is less than 0.05. In addition, all three instruments are considered reliable if Cronbach's Alpha value exceeds 0.70 (Taber, 2017). The test results in Table 3 show that all instruments have an r-count value $> r_{\text{table}}$ (0.349) with a significance $p < 0.05$. The results of the reliability test showed that the Cronbach's Alpha value of both instruments was above 0.70. Thus, the student response questionnaire instrument and numeracy skills test used can be declared valid and reliable.



2.4 Data Analysis

The validation process is carried out by two experts, namely learning evaluation experts and mathematics learning media experts. Experts are selected based on their experience and productivity in the field of learning evaluation and innovative mathematics learning media works. Before the expert assessment is carried out, it is first explained what aspects of the assessment are the focus and the assessment technique. Experts rate products using a Likert scale of 1–4, with a breakdown of 1 means disagree, 2 means disagree, 3 means agree, and 4 means agree. The validation data is then processed in the form of a score percentage. The criteria for the average score of validity are presented in Table 4.

Table 4. Validity test criteria

Average Score (%)	Category
$Score > 75$	Valid
$50 < Score \leq 75$	Quite Valid
$25 < Score \leq 50$	Less Valid
$0 \leq Score \leq 25$	Invalid

Table 4 explains that a product is said to meet the valid aspect if it has a score of more than 75%. The criteria that are assessed for validity by experts include content, language, and media. Furthermore, Table 5 shows the categorization of the practicality test based on the criteria that have been set. The assessment of the practicality trial questionnaire used a Likert scale score of 1-4. Score 1 disagrees, scores 2 disagree, score 3 agree, and score 4 strongly agree. Practicality data was obtained from the responses of students and teachers to the use of CT e-comics, then analyzed in the form of an average percentage of scores. The aspects that are assessed for each item of the practicality test statement include content, ease of access, communicative, and language.

Table 5. Practicality test criteria

Average Score (%)	Category
$Score > 60$	Practical
$40 < Score \leq 60$	Quite Practical
$20 < Score \leq 40$	Less Practical
$0 \leq Score \leq 20$	Impractical

According to table 5, CT e-comic products meet the practical aspects of being applied if they have an average score of more than 60%. The data obtained through the validation sheet and response questionnaire were analyzed using cumulative scores and categorization based on the final score. Meanwhile, those obtained using the numeracy test were analyzed through the SPSS 25 application. The effectiveness test of CT e-comics was analyzed by the statistical covariance analysis test (ANCOVA) with a significance level of 0.05 (5%). Before the ANCOVA test is carried out, the test is first analyzed whether it meets normality and homogeneity. Analysis techniques were applied to determine the impact of the influence of CT e-comics on improving students' numeracy skills.

3. Results

3.1 Analysis Stage

Interview with the Teacher

The first question focused on the difficulties experienced by students in learning mathematics. The summary of the response provided by the teacher is presented as follows:



"The difficulties faced by students are the lack of interest in mathematics subjects. In addition, students still find it difficult to solve problems associated with daily activities."

The response showed that the lack of interest in learning and contextual problems were the major difficulties for the students in relation to mathematics. The next question was related to the teaching materials used by teachers. The response provided by the teacher is presented as follows:

"The use of teaching materials in learning is still limited to the printed version, students tend to be bored and uninteresting".

The teacher reported that the use of printed teaching materials tended to be uninteresting and reduced the enthusiasm of students in learning. Therefore, the curriculum was required to be student-centered in addition to the utilization of technology in the learning process.

CT-Based E-Comic Needs Analysis

The data related to the CT-based e-comics needs were obtained from questionnaires given to students. The following is the result of the recapitulation of the questionnaire.

Table 6. CT-based comics needs analysis

S.No	Statement	Presentation			
		Strongly agree	Agree	Less agree	Disagree
1	Use of teaching materials in digital form	47%	53%	0%	0%
2	Interested in using comics teaching materials	65%	22%	13%	0%
3	Motivated to use CT e-comics in learning	13%	47%	24%	16%
Average		41.67%	40.67%	12.33%	5.33%

The average percentage of the students who answered strongly agreed and agreed to the questions related to the needs was 82.34% while those who disagreed were 17.66% as presented in Table 6. Most students agreed to the inclusion of different teaching materials such as comics and technology in learning. This showed the need for innovative and interesting teaching material in the form of comics combined with technology in order to provide easy and flexible access.

3.2 Design Stage

The design stage was initiated through the determination of the media to be used, the selection of content formats, and the production of the initial design. The media determined to design the CT-based e-comics product were Sketchbook and Canva. Moreover, the content format included covers, learning objectives, comic characters, concept maps, conversations, and CT practice questions. The initial design aspect consisted of the theme, character of the comic characters, the creation of the plot script, and the development of the e-comic in its entirety. Table 7 describes the framework for the production of the CT-based e-comics.

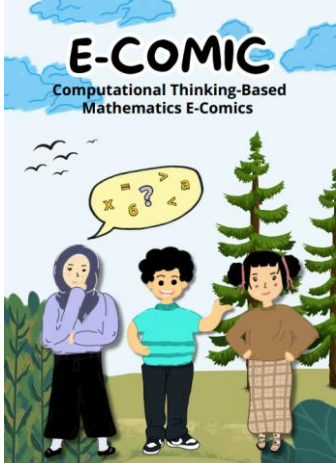









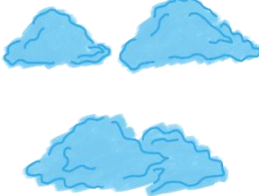


Table 7. CT-based e-comics design framework

Learning Objectives	Abilities to be Achieved	Uniqueness	The Elements	Material
Solving contextual problem	Numeracy skills	Based on Computational Thinking (CT)	Abstraction, representation, decomposition, algorithm, and evaluation	One-Variable Linear Equality and Inequality



Table 7 shows the learning objectives, abilities achieved, uniqueness of e-comics, CT indicators, and material learned. It was observed that contextual problems were designed to be solved through the stages of CT. Moreover, both variables were relevant to the determination of numeracy skills. The CT-based e-comics developed were considered to support the numeracy skills of students. Table 8 shows the design of this product with a focus on the comic characters, elements, covers, structures, dialogues, and CT elements.

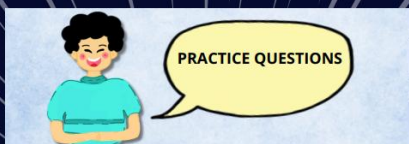
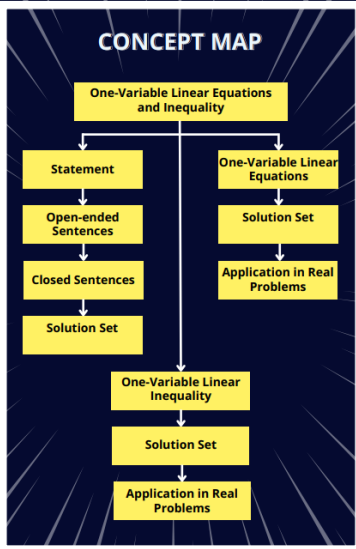
Table 8. CT-based e-comics design

Comics Section	Information									
	Cover									
<table border="1" style="width: 100%; text-align: center;"> <thead> <tr> <th colspan="3">Character</th> </tr> </thead> <tbody> <tr> <td data-bbox="129 976 360 1155">  <p>Naura</p> </td> <td data-bbox="400 976 632 1155">  <p>Fadil</p> </td> <td data-bbox="671 976 903 1155">  <p>Sabrina</p> </td> </tr> <tr> <td>Diligent</td> <td>Clever</td> <td>Want to learn</td> </tr> </tbody> </table>	Character			 <p>Naura</p>	 <p>Fadil</p>	 <p>Sabrina</p>	Diligent	Clever	Want to learn	Comic Character
Character										
 <p>Naura</p>	 <p>Fadil</p>	 <p>Sabrina</p>								
Diligent	Clever	Want to learn								
	Cloud elements									
	Bubble Dialog									
	Elements of comics									

Learning objectives, concept maps, practice questions, and answer sheets

LEARNING OBJECTIVES

1. Students are able to correctly determine the value of variables in a Single Variable Linear Equation
2. Students are able to correctly determine the value of variables in One-Variable Linear Inequality
3. Students are able to correctly model mathematical problems of contextual problems related to One-Variable Linear Equations and Inequality
4. Students are able to correctly solve real problems related to One-Variable Linear Equations and Inequality



1. Define the statements below that include an open sentence or a closed sentence using a checkmark (✓), and give the reason

No	Statement	Open	Closed	Reason
a.	The result of times 4 and -3 is -12			
b.	$m - 5 = 18$			
c.	Getuk goreng is a typical food of Sokaraja, Banyumas			
d.	A number plus 3 results in 21			
e.	12 less than 8			
f.	Seven times y equals thirty-five			

Dialogue in comics

<p>1. Jaidi bought 4 boxes of fried getuk at the same price per box, but Jaidi got a discount of IDR 6,000,-. After getting the discount, Jaidi still has to pay IDR 114,000,-</p> <p>a. Write down what information you know and ask about?</p> <p>Answer:</p> <p>Diketahui :</p> <p>1) A lot of fried getuk bought = Fried Chicken Box</p> <p>2) Amount of money paid = IDR</p> <p>3) Discount = IDR</p> <p>Asked:</p> <p>How much does a box of fried getuk cost that Jaidi bought before getting a discount?</p> <p>b. Write the information using symbols or notation mathematics?</p> <p>Answer:</p> <p>Suppose:</p> <p>..... =</p> <p>Mathematical Model:</p> <p>.... - 6.000 =</p>	<p>Elements of Computational Thinking (CT)</p>
<p>c. How much does a box of fried getuk cost that Jaidi bought before getting a discount?</p> <p>Answer:</p> <p>From these equations, then:</p> <p>..... - 6.000 =</p> <p>..... = +</p> <p>..... =</p> <p>..... =</p> <p>d. Based on the results of your work, what conclusions have you drawn?</p> <p>Answer:</p> <p>.....</p> <p>.....</p> <p>.....</p>	

3.3 Development Stage

The CT-based e-comic product was subjected to a validation test before implementation. This was conducted through the adoption of a school teacher with relevant experience and competence as the material expert. Meanwhile, the media experts were practitioners in the field of digital-based interactive media with innovative products recognized at the national or international level. The results obtained from the validation analysis are presented in the following Table 9.

The results obtained from the validation analysis are presented in the following Table 9.

Table 9. Validation test results

No	Criteria	Percentage	Category
Material Expert			
1	Content Eligibility	79%	Valid
2	Presentation Eligibility	88%	Valid
3	Language Qualifications	83%	Valid
4	Elements of Computational Thinking	76%	Valid
Media Experts			
1	<i>Usable</i>	88%	Valid
2	Functional	83%	Valid
3	Design and Appearance	94%	Valid



The validation by the material expert showed that the product was at an average of 81.25% and the media experts reported 88.33%. Both results showed that the CT-based e-comics developed was in the valid category. However, several small inputs were made on the format followed by improvements in line with the recommendations.

3.4 Implementation Stage

Another class with a total of 32 students was selected to conduct a practicality test. This was achieved by using the CT-based e-comics for learning at three meetings as presented in Figure 2.



Figure 2. Students using the CT-based e-comics

The students used the CT-based e-comics in discussions with a focus on the content of the conversation by several figures and understanding of the examples related to the problems presented in the completion process. The contextual problems contained in the product were also solved by the students. This condition showed that the CT-based e-comics were highly interactive and supported numeracy skills. The results from the practicality test are presented in the following Table 10.

Table 10. CT e-comic practicality test

No	Criteria	Percentage	Category
1.	Content design	79%	Practical
2.	Communication	88%	Practical
3.	Ease of access	88%	Practical
4	Language	77%	Practical
Average		83%	Practical

The practicality test conducted showed that the product was classified in the category of practical. Each criterion which ranged from the content design, communication, ease of access, and language was observed to be in the practical category. These results proved that the CT-based e-comics were practical and useful for subsequent application in improving the numeracy skills of students.

The results of the practicality test (average 83%) can be translated into some concrete design recommendations. High scores on the communication aspect (88%) indicate that students are greatly helped by clear storylines, communicative dialogues, and visual-text integration, so this feature needs to be maintained and strengthened as a means of scaffolding concepts. Similarly, ease of access (88%) indicates that the media is quite user-friendly, but for wider implementation, it is necessary to prepare a lightweight/offline version and be compatible with low-spec devices to overcome the limitations of technology in schools. In contrast, content design (79%) and language (77%) scores indicate barriers. Information density and visual display that are not optimal have the potential to increase cognitive load, so it is necessary to simplify panels, segment materials, and affirm visual focus. In terms of language, the use of terms needs to be simplified and supported by additional explanations so as not to

hinder understanding. In addition, extensive implementation requires the readiness of teachers as facilitators through short training, as well as the management of learning time (60–90 minutes) by dividing content into flexible modules. With these improvements, CT e-comics can be used more effectively and adaptively in various classroom contexts.

3.5 Evaluation Stage

The next stage was to determine the effectiveness of the CT-based e-comics in improving numeracy skills. Previously, Table 11 was presented regarding the results of pretest and post-test descriptive statistics for each experimental class and control on the value of students' numeracy skills.

Table 11. Descriptive statistics of numeracy skills

Items	Class	N	Mean	Std. Deviation	Std. Error Mean
Pretest	Control	32	50.91	11.318	2.001
	Experimental	32	50.64	11.376	2.107
Posttest	Control	32	61.01	14.112	2.523
	Experimental	32	82.51	12.106	2.112

Based on table 11, the average numeracy skills score in the control class has a score difference of 10.1 between the pretest and posttest. In contrast to the experimental class, there was a significant increase in the average numeracy skills before and after learning of 31.87 with a posttest score of 82.51. Thus, learning that applies CT e-comics has an average score of good numeracy skills and a significant improvement.

Next, the results of the normality and homogeneity test results of students' numeracy skills tests are presented. Table 12 and table 13 show the results of the SPSS normality and homogeneity test, respectively.

Table 12. Normality test

Variable	Class	Shapiro-Wilk		
		Statistic	df	Sig.
Pre Test	Control	0.129	0.129	0.109
	Experimental	0.071	0.073	0.073
Post Test	Control	0.105	0.155	0.125
	Experimental	0.158	0.158	0.145

Table 13. Homogeneity test

Variable	Item	Levene Statistic	Sig.
Pre test	Based on Mean	2.477	0.069
Post test	Based on Mean	3.309	0.172

Table 11 shows that the significance value in the posttest was 0.125 for the control class and 0.145 for the experimental class. For the pretest, each experimental and control class had significance values of 0.109 and 0.073. Both values are greater than 0.05 so it can be concluded that the data is normally distributed. Furthermore, in Table 12, an average significance value of 0.069 was obtained for the pretest while for the posttest a significance value of 0.172 was obtained, both of which also exceeded 0.05, thus showing that the data is homogeneous. Because the



normality and homogeneity requirements have been met, the analysis was continued using the ANCOVA test. Table 14 presents the results of the ANCOVA exam.

Table 14. Results of the ANCOVA test

Univariate Test						
Dependent variable: Posttest						
	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Square
Contrast	2291.327	2	2291.319	69.766	0.000	0.431
Error	2190.903	61	33.208			

Table 13 shows the results of ANCOVA's analysis which shows a significance value of 0.000 which is smaller than 0.05. These results show that the use of CT e-comics in learning has a significant influence on improving students' numeracy skills.

The findings of this study show that the use of e-comics in mathematics learning in general has a positive impact on improving numeracy skills, especially in understanding concepts and problem solving. However, compared to some previous studies that emphasized improving general learning outcomes or learning motivation, this study made a different contribution by highlighting computational thinking-based cognitive mechanisms (CT) as the main factor for improvement. Other studies tend to use e-comics as contextual visual media, whereas in this study e-comics are explicitly designed to facilitate decomposition, representation, and algorithmic processes, so that the increase in numeracy occurs not only due to motivational aspects, but also due to the involvement of high-level thinking processes.

To provide a clearer picture, Figure 3 presents a data visualization of the average N-Gain value between pretest and **posttest** results in each experimental and control class for each numeracy indicator.

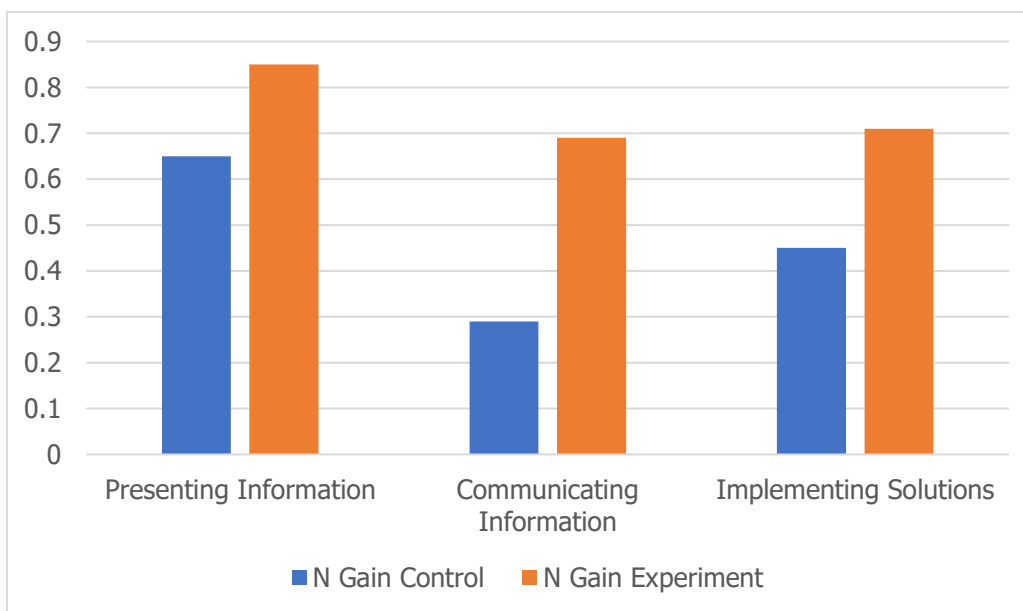


Figure 3. Average increase in numeracy indicators

Based on Figure 3, it can be seen that each numeracy indicator shows a difference in the average N-Gain value between the experimental class and the control class. Across all indicators, the average value of N-Gain in the experimental class was higher than in the control class. This indicates that the treatment applied to the experimental class has a positive effect on improving numeracy skills in each indicator. The greatest improvement in the indicator, presenting information and implementing solutions, increased scores of 0.85 and 0.71, respectively. This condition is achieved because the design of the CT e-comic presents contextual problems that are close to students' lives so



that it makes it easier to understand the initial information and the storyline and the completion process are presented in CT steps that are more systematic, simple, and easy to solve part by section.

4. Discussion

CT's innovative e-comic product shows some uniqueness with previous comic products in terms of improving student numeracy, presenting local contextual problems, positive characters in comic characters, and integrating computational thinking (CT) stages in problem solving. Precise and effective results of the analyses conducted showed the skills of CT-based e-comics to solve contextual problems such as numeracy. The trend showed that the CT-based e-comics was able to improve the cognitive abilities, especially numeracy, of students. This was in line with the previous results of [Aprilia *et al.* \(2023\)](#) and [Siagian *et al.* \(2024\)](#) that comics could develop numeracy skills, cognitive abilities, 21st-century skills ([Trimurtini *et al.*, 2020](#)), and critical thinking ([Krusemark, 2016](#); [Lestari *et al.*, 2021](#)). Comics were also reported to have a functional role in mathematics education to assist teachers in ensuring a more appropriate and effective learning process ([Fitriani & Leton, 2024](#)).

The CT steps were integrated into the conversation and discussion process of the e-comics developed in this research in order to improve numeracy skills. This was considered important to solve problems structurally and comprehensively through the stages of abstraction, representation, decomposition, algorithms, and evaluation ([Ferdianto *et al.*, 2025](#); [Lyon & J. Magana, 2020](#)). The integration of CT to solve different contextual and complex problems can assist in improving the numeracy skills of students. The same trend was reported by [Lee *et al.* \(2024\)](#) and [Zhang & Gary \(2023\)](#) that the development of CT-based instruments was effective in developing numeracy, logical thinking, and analytical skills. The introduction of the method in the current e-comics is part of the innovations needed to improve numeracy. This was observed through the skills of the students to understand problems effectively and solve numeracy problems correctly. The observation was supported by [Yang *et al.* \(2026\)](#) that the CT method was suitable for mathematics learning in order to support numeracy skills.

The CT-based e-comics can solve the problems related to the daily lives of students. This was due to the presentation of comics in the form of a light contextual storyline and the arrangement through interesting interactive images to arouse imagination and attract readers ([Wati, 2022](#)). Moreover, CT-based e-comics could guide students directly to solve contextual problems systematically through sequential working processes ([Aminah *et al.*, 2022](#); [Gunawan *et al.*, 2024](#)). This is achieved by breaking down complex problems into small pieces in order to provide simple solutions. The method allows the students to focus on the explanation of the teachers and also participate more actively in the completion process. Students are assisted to easily understand and solve problems because the conversations in the CT e-comic are adopted from the context of daily life ([Saputri & Qohar, 2020](#)). The process ensures the mathematics learning process becomes more meaningful because the problems solved are close to the students ([Paraol & Stormowski, 2022](#); [Pratiwi *et al.*, 2019](#)).

The results of the study have implications for the professionalism of educators in the application in the school environment, diverse learner profiles, and the flexibility of numeracy topics in comics. First, educators are required to innovate by integrating learning models into teaching materials such as comics. It is also observed that comics are not a substitute for learning methods but are expected to serve as a support for the process. The trend shows the need for optimization through the collaboration of comic teaching materials and learning models to achieve more effective results ([Fang *et al.*, 2023](#); [Damopolii *et al.*, 2021](#); [Fitriani & Leton, 2024](#)). Second, the product developed in this research had a positive impact on student character. The trend shows that the integration of local cultural values in the learning curriculum is an innovation to be developed in order to form positive character values ([Norton & Duke, 2021](#)). The recommendation was in line with the observation of [Kamaruddin \(2012\)](#) and that the integration of elements of local wisdom in the learning process could increase character values for the students. Third, in addition to having an impact on student learning outcomes, the use of comics is also a form of innovation in learning that has consequences for the professional development of teachers related to the flexibility of the content of the numeracy topics used. The application of this media requires teachers to improve pedagogical skills, especially in integrating cultural content elements, collaboration between numeracy topics, encouraging high-level thinking skills, and managing an interactive learning atmosphere. Although engaging and interactive media can increase student engagement while reducing boredom, its success still depends heavily on the presentation of topics that match the profile of students' abilities and the quality of the learning process itself. This is in line with the findings of [Hursen *et*](#)



al. (2023) who affirm the importance of resilience and diverse competencies in facing the challenges of the 21st century, and Daniel et al. (2024) who show that creative and engaging learning is able to create a more effective learning environment and support students' conceptual understanding.

5. Conclusion

In conclusion, CT-based electronic comics are identified as innovative products that meet the validity and practicality tests leading to the possibility of providing convenience and flexibility. In addition, CT e-comics are effective in improving students' numeracy skills as evidenced by ANCOVA test results that meet the effective criteria. The presentation of local contextual problems, the use of positive characters in comic characters, and the problem-solving process that applies computational thinking processes are the advantages of this innovative product. The results of the study have positive implications for a meaningful and enjoyable learning process as well as the development of teachers' professional competencies.

However, some limitations in this study need to be noted in interpreting the results. The study was conducted only in one school with a limited number of samples, so the results may not be widely generalized. In addition, the relatively short time of implementation of the intervention limited the drawing of conclusions related to the sustainability of improving students' numeracy skills. This study also does not fully control external factors such as variations in teaching styles, classroom conditions, and students' initial abilities that have the potential to affect the results obtained.

Several recommendations are provided to develop e-comics based on local wisdom such as culture, local tourism potential, and culinary. This is because the integration of local culture into the context of the problem can increase the interest of students in learning. The process is also capable of enhancing the awareness and understanding of the students about the prevailing culture within the environment. Moreover, the method can also improve the awareness of the students in relation to the preservation of local culture. The products developed through the research can be considered in the formulation of curriculum policies in schools related to the integration of local wisdom into the learning process.

Further research is needed to redevelop the CT-based e-comics media due to certain limitations identified in relation to the material, subject aspects, and advanced evaluation methods. First, the product developed was limited to the material of the one-variable linear equation and inequality system. This can be improved through the inclusion of geometry material to ensure the product serves as a learning resource for enhancing spatial skills. Second, the subject was limited to the junior high school environment. This shows the need for the addition of elementary school because the students are often trained in reading culture and literacy skills from an early age. Third, further studies on the relationship between computational thinking skills and numeracy skills still need to be deepened. A qualitative approach can be used to explore the characteristics of computational thinking and numeracy of students. Quantitative research can be passed on to the improvement of not only numeracy but also computational thinking. On the other hand, the use of mixed method design that combines quantitative analysis with qualitative deepening has the potential to provide a more comprehensive picture of the interaction of the two constructs in the context of contextual-based digital learning.

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Acknowledgement

The authors are grateful to the Universitas Muhammadiyah Purwokerto, Universitas Swadaya Gunung Jati Cirebon, and Universitas Indraprasta PGRI for supporting this research.

Authors' Contributions

Gunawan: Conceptualization, Methodology, Writing-Original Draft. Azhyzhah Noer Utami: Formal analysis, Resources. Ferry Ferdianto: Data Curation, Investigation, Writing-Review & Editing. Fauzi Mulyatna: Formal analysis, Visualization, Supervision. Lukmanul Akhsani: Formal analysis, Visualization. All the authors have read and agreed to the published version of the manuscript.



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Yes

Conflict of Interest

The authors have no conflicts of interest to declare. There is also no financial interest to report. The author certifies that the submission is original work and is not under review at any other publication.

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Cite this Article

Gunawan, Azhyzhah Noer Utami, Ferry Ferdianto, Fauzi Mulyatna, Lukmanul Akhsani, Development and Evaluation of Computational Thinking Based Mathematics E-Comics for Enhancing Numeracy Skills in Junior High School Students, Asian Journal of Interdisciplinary Research, 9(2), (2026) 25-46.
<https://doi.org/10.54392ajir2622>