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DEVELOPMENT OF DIGITAL WORKSHEETS ASSISTED BY GEOGEBRA ON LINEAR FUNCTION MATERIAL TO SUPPORT STUDENTS COMPUTATIONAL THINKING SKILLS

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ABSTRACT

This study aims to develop a valid and practical digital worksheet in GeoGebra on linear functions, with a focus on the dangers of waste, to support students' computational thinking skills. This study employed a design research type of development studies, referring to three stages: preliminary research, prototyping phase, and assessment phase. The validation involved three mathematics education lecturers and one mathematics teacher during the expert review stage. It was then carried out in parallel at the one-to-one stage with three students, while the practicality test was conducted with six eighth-grade students during the small-group trial. Then, the validation employed the walkthrough method using observation sheets during the expert review stage, and the one-to-one stage also applied the walkthrough method with observation notes on student performance to record students responses. Practicality was evaluated through student response questionnaires using a Likert scale during the small-group trial. The results showed that the digital worksheet using GeoGebra had an average validity of 93.81% (very valid) and practicality of 82.18% (practical). Therefore, the developed GeoGebra-assisted digital worksheet was considered valid and practical for mathematics learning and has the potential to foster students' computational thinking skills through contextual mathematical problem-solving related to environmental issues.

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1. INTRODUCTION

In the 21st century, education is not only focused on mastering factual knowledge but also demands that participants educate themselves to develop higher-level thinking skills (Mashudi, 2021). These skills include critical thinking, problem solving, creativity, collaboration, communication, and computational thinking, skills now recognized as key competencies in the digital era (Csizmadia et al., 2015; OECD, 2023; Wing, 2011). Mastery skills are viewed as important because they equip young people to address complex problems in the real world, including social, technological, and environmental ones (Aslamiah et al., 2021). Among various 21st-century skills, computational thinking has gained particular attention due to its interdisciplinary nature and close relation to problem-solving (April et al., 2024). Computational thinking is a framework that helps students solve problems systematically through four primary indicators: decomposition, introduction patterns, abstraction, and algorithmic step-by-step arrangement (Wing, 2008). In line with that, research (Shute et al., 2017) shows that computational thinking can push students to develop a resolution strategy for more structured and efficient problem-solving. As mentioned, computational thinking is highly relevant to integrating into mathematics instruction to help students think logically and organize themselves to address various real-world problems (Mardianto & Yahfizham, 2024).

Mathematics, as one of the key fundamental lessons, plays a strategic role in forming skills, particularly in the ability to think logically, analytically, and computational (Ye et al., 2023). However, Indonesian students' achievements in international assessments remain low (OECD, 2023). Based on PISA 2022 results, Indonesia ranks 71st out of 81 countries. The average mathematics score is 366, far below the OECD average of 472 (Pulungan, 2022). This condition confirms the need for innovation in mathematics learning to help students not only understand concepts but also apply them to real-world contexts (Zulkardi & Putri, 2019).

For the answer challenge mentioned, it is necessary to give specific attention to the curriculum materials that serve as a runway for a deeper understanding of mathematics (Palias & Mampouw, 2020). One of them is a linear function, which plays an important role in introducing the connection between variables, representing equations, and interpreting charts (Putri et al., 2022). In addition, the material is very close to daily life (Putri et al., 2022). Linear functions are used, for example, to model growth, savings, transportation costs based on distance, monthly electricity use, and the amount of waste produced in an area over time (Kuswandi et al., 2025). In other words, the linear function provides students with a chance to see the direct relationship between mathematics and real-world phenomena (Nugraha, 2024). However, this research shows that students still face difficulty in understanding and applying linear functions in contextual situations (Palias & Mampouw, 2020). Reporting that students often fail to connect data with mathematical models, misinterpret the gradient and constant, and are not capable of drawing interesting conclusions from the given graph (Nafisa Aulia, 2021). Difficulties indicate that learning linear functions still focuses on mechanical procedures and temporary conceptual understanding, and that its application in real contexts is not optimal (Gowasa, 2022; Mahmudin, 2022).

This condition highlights the need for more innovative, visual, and interactive teaching tools. One of the potential solutions is the development of a digital worksheet, which is enriched with integration device software, such as GeoGebra (Cahyana et al., 2024; Hapsari et al., 2024). GeoGebra allows you to visualize functions, manipulate parameters, and explore them through interactive charts. Various studies show that the use of GeoGebra can increase understanding of concepts, improve the representation of skills, and increase motivation. Study student (Hamady et al., 2024). Integration of GeoGebra into digital worksheets allows students not only to inspect the return results calculations, but also to deepen their understanding of mathematics through interactive visual representations (Ramadannia et al., 2024).

Previous studies have developed various electronic student worksheets, such as those using Liveworksheets (Fitri et al., 2024), GeoGebra integration (Cahyana et al., 2024), and using the context environment land wet (Rahman et al., 2023). However, few have contextualized them within environmental issues relevant to students' daily lives. The novelty of this study lies in the integration of GeoGebra-assisted digital worksheets with environmental contexts, particularly waste issues, to foster students' computational thinking. Context this chosen because issue environment is problem relevant real with life student at a time be one of focus in PISA 2025, which integrates literacy climate and science in global (OECD, 2024) With utilize related data the danger of waste, students invited for building mathematical models use linear function, analyzing connection between variables, as well as predict its impact in the future. Approach this expected capable practice in computational thinking skills for students through activity decomposition, pattern recognition, abstraction, and algorithmic thinking. Furthermore, this study also aligns with several Sustainable Development Goals (SDGs), namely SDG 4 (Quality Education), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action), by promoting awareness and problem-solving related to environmental sustainability (Affairs, 2024; Arora & Mishra, 2019).

Therefore, this study aims to develop and analyze the validity and practicality of a GeoGebra-assisted digital worksheet on linear function material designed to support students' computational thinking skills through the context of the danger of waste. The results of this study are expected to serve as a foundation for further research related to the effectiveness of the product in improving students' computational thinking skills.

2. METHOD

This study employs a development research design referring to the three stages of the Plomp (2013) namely the preliminary research, prototyping phase, and assessment phase. During the prototyping phase, the process was based on formative evaluation (Tessmer, 1993), which consists of self-evaluation, expert review conducted in parallel with one-to-one evaluation, small-group evaluation, and field testing. The following figure illustrates the stages of the formative evaluation.

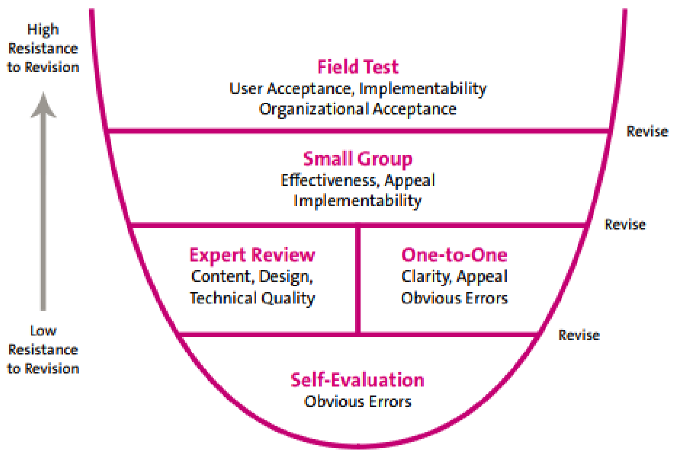

Figure 1 Formative Evaluation (Tessmer, 1993)

However, this study was limited to the prototyping phase, which included small-group trials, since it only focused on analyzing the validity and practicality of the developed product. Research uses a mixed-methods approach (qualitative and quantitative). The research subjects were eighth-grade students of SMP Negeri 32 Palembang, consisting of three students involved in the one-to-one stage and six students in the small-group trials. In addition, three mathematics education lecturers and one mathematics teacher were involved as expert reviewers during the validation process. The procedure study consists of two main stages.

The preliminary research stage involved curriculum, material, and student needs analyses. It also included mapping the stages of computational thinking (decomposition, pattern recognition, abstraction, and algorithmic thinking) into contextual problem tasks. Then development or prototyping phase, during the prototyping phase, four main activities were conducted:

1. Self-evaluation, the evaluation conducted to design the initial version of the digital worksheet, which resulted in Prototype I;
2. Expert review, validation by three mathematics education lecturers and one mathematics teacher focusing on content, construct, language, and ICT aspects
3. One-to-one, testing prototype I on three students with high, medium, and low abilities to produce prototype II;
4. Small group, testing prototype II on two groups (six students) to assess practicality and refine prototype III.

The assessment phase was conducted as a semi-summative evaluation to assess the validity and practicality of prototype III with the criteria that have been set. Focus stage: This is evaluated through expert review and one-to-one results, as well as practicality through small-group trials. The goal is to determine to what extent the product meets the indicator's validity and practicality. Data were collected through validity and practicality questionnaires as well as interviews. Qualitative data from expert comments and interviews were analyzed descriptively to improve the product design. While the quantitative data questionnaire validity is based on the guidelines, the category evaluation sheet validation is as follows.

Table 1 Category Validation Sheet Assessment

Score	Category
4	Very good
3	Good
2	Enough
1	Not good

Then, I analyzed the use of the formula.

$$Score = \frac{The\ total\ score\ obtained}{The\ maximum\ score} \times 100\%$$

Validity of analysis results is categorized according to (Akbar, 2013).

Table 2Validity Table

Validity Level	Criteria Validity
85.1% - 100%	Very valid
70.1% - 85%	Valid
50.1% - 70%	Quite Valid
0.1% - 50%	Invalid

Then, a practical data score was counted using a Likert scale. The questionnaire was then categorized according to the table below.

Table 3 Guidelines Scoring Questionnaire Practicality

Statement	Answer Score			
	SS	S	TS	STS
Positive	4	3	2	1
Negative	1	2	3	4

(Sudjana, 2013)

Information :
SS = Strongly agree
S = Agree
TS = Disagree
STS = Very much not agree

Then, determine the presentation of every indicator on the sheet questionnaire using the formula :

$$N_p = \frac{The\ total\ score\ obtained}{The\ maximum\ score} \times 100\%$$

Determining the average percentage mark of practicality with a formula :

$$N_a = \frac{The\ percentage\ obtained}{The\ number\ of\ items} \times 100\%$$

Determine the category practicality of digital worksheet based on following criteria:

Table 4 Criteria Practicality

Score (%)	Criteria Practicality
$84 \leq N_a \leq 100$	Very Practical
$68 \leq N_a < 84$	Practical
$52 \leq N_a < 68$	Less practical
$36 \leq N_a < 52$	Impractical
$20 \leq N_a < 36$	Very Impractical

(Sugiyono, 2015)

3. RESULTS AND DISCUSSION

3.1. Results

Preliminary Research Phase

In the preliminary research stage, a needs analysis and initial product design were conducted. In the needs analysis, researchers conducted interviews with junior high school mathematics teachers in Phase D to identify initial learning conditions related to the use of digital media, computational thinking skills, and students' ability to solve problems involving linear functions. The interview results showed that GeoGebra-assisted digital worksheets had never been used in learning, and the methods used were still conventional, such as discussions and direct teacher explanations. This condition resulted in students' computational thinking skills decomposition, pattern recognition, abstraction, and algorithms being underdeveloped, and their ability to solve contextual problems remained low. Based on these findings, researchers analyzed the curriculum, materials, abilities, and needs of students, and examined the relationship between the stages of computational thinking and the context of waste hazards to compile relevant mathematical problems. In addition, researchers developed research instruments, such as validation sheets and computational thinking rubrics, to support the development process. The next stage was the design of GeoGebra-assisted digital worksheets that integrate the stages of computational thinking into learning activities on linear functions in the context of waste.

Development or Prototyping Phase

Self-evaluation

This stage involved a detailed review of the initial digital worksheet design as part of the self-evaluation process. Activities this covers improvement design from side content, appearance, and integration with stages of computational thinking (decomposition, pattern recognition, abstractions, and algorithms). Researchers designing digital worksheets using the Canva app to arrange visual displays and utilizing the Top Worksheets platform to compile them. Adjustments were made to technical aspects such as election color, layout, illustrations, size, and typeface to make the digital worksheet display more engaging and easier to read. Every activity in the digital worksheet is aligned with the objective of learning linear functions and context danger the rubbish that is lifted, and is designed based on computational thinking steps that begin with decomposition, pattern recognition, abstraction, and algorithm, so that students can think systematically in solving the problem. After the revision and refinement process was completed, prototype 1 was produced in the form of a digital worksheet, assisted by GeoGebra, that was customized with a linear function to support students' computational thinking abilities. The following is the beginning of the digital worksheet in Figure 1.

Figure 2 Initial Display of Digital Worksheet

Next, there are activities in a digital worksheet learning videos about linear functions are embedded, then a video about context, danger, waste that becomes data for a problem in the digital worksheet, and embedding GeoGebra for students to check return functions and explore direct relationships between variables. Figure 2 illustrates interactive components in the digital worksheet, including embedded videos and GeoGebra tasks that support problem exploration. The following picture is for a digital worksheet.

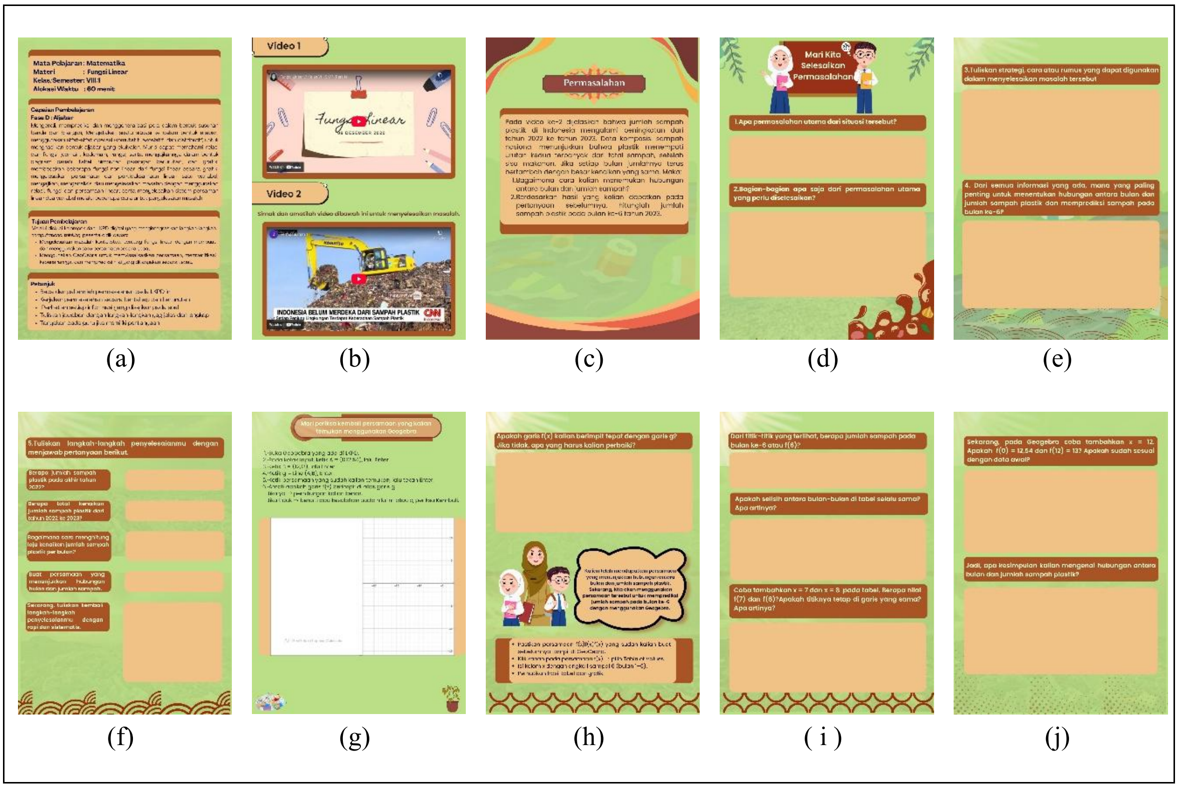

Figure 3 Digital Worksheet Prototype I Activities

Expert Review

At this stage, the validation process was conducted by three mathematics education lecturers and one junior high school mathematics teacher, who served as experts and assessed the product's quality across various aspects, namely content, construction, language, and technology (ICT). The experts' assessment aimed to ensure the material's alignment with the curriculum, the accuracy of the application of the computational thinking stages, the clarity of the language, and the suitability of the digital design to student needs. The purpose of this assessment was to assess the feasibility of the developed prototype 1 digital worksheet assisted by GeoGebra. The validation results served as the basis for revising and improving the digital worksheet. At the same time, comments and input from the validators were used to strengthen areas that remained weak, making the product better suited for use in the next trial stage. A summary of the assessment results and the validators' suggestions is presented in Table 5.

Table 5 Validator Comments and Suggestions

Validator	Comments and Suggestions	Revision Decision
Validator 1	Suggested improvements in mathematical symbols and clarity of question wording.	Revised mathematical symbols and refined question to specify units and rounding.
Validator 2	Recommended clearer GeoGebra instructions, alignment of fonts, correction of writing errors, and	GeoGebra instructions improved, writing errors corrected, fonts aligned, and display features enhanced.

	improving the display of GeoGebra and videos.	
Validator 3	Suggested correcting wording of the function equation question and adjusting worksheet signs.	Revised question wording and adjusted symbols/signs in the worksheet.
Validator 4	Recommended adding more appropriate learning videos and improving mathematical symbols in videos.	Added additional videos and corrected mathematical symbols in learning videos.

Table 6 Validation Results

Aspect	Percentage	Category
Content	94.32%	Very Valid
Construct	95.62%	Very Valid
Language	90%	Very Valid
ICT	95.31%	Very Valid
Average	**93.81%**	**Very Valid**

The validation results by three mathematics education lecturers and one mathematics teacher indicated an average validity score of 93.81% (very valid). In detail, the content aspect obtained a score of 94.32%, construct 95.62%, language 90%, and ICT 95.31%. These results indicate that the developed digital worksheet has met the validity criteria in terms of the suitability of the content to the curriculum, the accuracy of the presentation structure in accordance with computational thinking indicators, the clarity of the communicative language and its ease of understanding for students, and the feasibility of the technology used. Thus, the GeoGebra-assisted digitam worksheet is highly suitable for learning.

One-to-one

This stage runs parallel to the expert review stage. In this stage, researchers involved three students representing the high, medium, and low ability categories, selected based on recommendations from their subject teachers. Students were asked to try out some of the activities in the GeoGebra-assisted digital worksheet and provide direct feedback regarding the clarity of instructions, ease of use, and the appearance of the digital worksheet. This process aims to assess the understandability of the content and the suitability of the digital worksheet design to students' abilities in the field. The reflection results from the expert review stage, along with the findings from the one-to-one stage, served as the basis for revisions to produce an improved prototype 2, ready for testing in the next stage. Below are some findings from the one-to-one stage.

Table 7 Findings at the One-to-One Stage

No	Student Comments and Suggestions	Revision Decision
1	Student difficulty in writing formula gradient-shaped fractions, due to limitations of the equation feature in digital worksheets	Add an equation feature in digital worksheets so that students can write formulas, especially for fractions on the gradient, more easily and in a mathematical format

2	Students need more time; they are not arranged for their time workmanship with Good.	Add a timer to the digital worksheet.
3	Students have difficulty understanding the parts of the question in the problem	's central part. The revision is not complete; however, the researchers provide direct guidance so that students understand the meaning of the question.
3	Student difficulty in understanding the problem.	The revision is not complete; however, the researchers provide direct guidance so that students understand the meaning of the question.
4	Students have difficulty writing a conclusion because they are not yet accustomed to putting their thoughts into writing, even though they can explain them orally.	The revision is not done, the researcher only gives instructions for students who are more used to writing a conclusion in a systematic way in accordance with the results of their work.

Small group

Stage This involves six students who are divided into two groups, each consisting of three people. Activities. The aim is to evaluate the practicality of digital worksheet assisted by GeoGebra through four aspects of assessment convenience of access and use, understanding of content, attractiveness of display, and the benefits of technology in digital worksheets. At this stage, students work in groups to complete the activity in a digital worksheet, then respond to the fourth aspect by filling out the questionnaire, using practicality as a basis for product improvements and refinements. The following Student comments and suggestions at the small group stage are shown in Table 8, and the results of the practicality in Table 9 below :

Table 8 Small Group Comments

Initials Student	**Comment Student**
MRAT	This digital worksheet makes make clear that there is a relationship between problems in daily life and lessons in mathematics.
AF	GeoGebra helps me answer much more easily and quickly.
RSM	I like it because there is a video about dangerous rubbish. This make me understand more about the dangers of waste to the environment.
MRT	The video material in the digital worksheet is interesting, short, and clear.
MAR	Problem video helps understand the problem.
SA	An easy digital worksheet is used, and it looks interesting.

Table 9 Practical Results

Aspect	Percentage	Category
Ease and Accessibility	82.5%	Practical
Understanding Content	81.66%	Practical
Attraction Appearance	81.25%	Practical
Benefits of Technology in digital worksheet	83.33%	Practical
Average	**82.18%**	**Practical**

Based on results in the small-group stage, the digital worksheet assisted by GeoGebra achieved an average practicality of 82.18% across the practicality aspects: convenience of access and use, understanding content, attractiveness, appearance, and usability of the technology. Comments from students show that the digital worksheet helps them understand the relationship between real-world problems and mathematics lessons, and that assessing contextual videos and using GeoGebra make the activity more interesting and easier to understand. This result shows that the digital worksheet is practical and feasible for learning contextual linear functions.

Assessment Phase

The assessment phase confirmed that the third prototype met the expected validity and practicality criteria, with respective scores of 93.81% (very valid) which shows that the digital worksheet is in accordance with the curriculum, structure, presentation, language use, and integration of technology. The high validity score indicates strong alignment with computational thinking indicators and curriculum objectives. Meanwhile, practicality 82.18%. in the practical category, indicating that the digital worksheet is easy to use, the content is well understood, looks interesting, and features technology functioning optimally. Comments from students also strengthen results, where they feel the digital worksheet helps them understand the connection between problem environment and mathematical concepts, as well as make learning more interesting through the use of contextual videos and GeoGebra. Thus, it can be concluded that the prototype 3 digital worksheet assisted by GeoGebra has fulfilled the criteria for validity and practicality, there is worthy of use as a learning medium for the material on contextual linear functions and danger waste, to support students' computational thinking abilities, and supports the development of students' computational thinking skills through contextual problem-solving activities.

3.2. Discussion

In terms of validity, the digital worksheet showed high scores, consistent with expert validation, indicating that the material, construct, language, and technology were in accordance with academic standards. These findings are consistent with Ardiansah & Zulfiani (2023), who reported similar validity results in developing electronic worksheets for creative thinking that obtained an average validity of 90.06% as well as the validation of Expression Learning-based e-worksheets that received a score of > 89% in construct and design (Pratiwi et al, 2023). In addition, research on the development of digital mathematics teaching materials also reported that valid products can support improved learning outcomes (Amir et al., 2025).

In terms of practicality, the digital worksheet demonstrated ease of access and use, content comprehension, attractiveness, and the usefulness of the technology, as reported by students during the small-group phase. These results align with research on Live Worksheets-based mathematics modules, which showed 86% of students responding in the very practical category, indicating that digital media is easy to use and supports active learning (Asfrianti & Gusmania, 2024). Furthermore, research on the development of contextual electronic student worksheets based on digital media also showed that students considered the media practical and easy to operate in mathematics learning because of its attractive appearance and clear instructions (Azzahro & Handayani, 2025). These findings align with research on the development of GeoGebra-integrated worksheets in project-based learning, which demonstrated validity, practicality, and effectiveness, strengthening the argument that integrating GeoGebra's dynamic features facilitates concept exploration and task execution on digital worksheets (Wahyuni et al., 2023). Although the worksheet is valid and practical, further research should examine its effectiveness in improving computational thinking performance across diverse student groups.

Overall, the validation and practicality test results indicate that the prototype 3 GeoGebra-assisted digital worksheet meets the criteria for classroom-ready learning products and aligns with the principles of 21st-century learning by promoting interactive and problem-based learning environments. High validity values indicate that the content, structure, and language of the digital worksheet align with the learning objectives and principles of computational thinking. Meanwhile, the practicality results show that students find the digital worksheet easy to use, the display is attractive, and it helps them understand the concept of linear functions in the context of the danger of waste. This suggests that the integration of GeoGebra facilitates decomposition and pattern recognition processes, which are key elements of computational thinking. These findings are in line with Hapsari et al. (2024), who found that GeoGebra-assisted digital worksheet helps students learn visually and improve their understanding of mathematical concepts through interactive graphic exploration. Similarly, Badriyanto & Qohar (2022) emphasized that integrating GeoGebra into digital worksheets can enhance learning effectiveness by making it easier for students to understand the relationships among variables in linear functions. highlighted that GeoGebra integration enhances conceptual understanding by visualizing variable relationships in linear functions. Then, Astuti et al. (2025) showed that the use of digital interactive media such as GeoGebra not only increases student engagement but also strengthens their ability to think computationally systematically. The findings provide implications for designing digital learning materials that incorporate computational thinking frameworks and sustainability contexts in mathematics education.

4. CONCLUSION

Based on the research findings, the GeoGebra-assisted digital worksheet on linear functions in the context of the danger of waste waste was found to be valid and practical. The obtained validity score of 93.81% and practicality score of 82.18% indicate that the developed digital worksheet meets the established criteria for content, language, design, and technology.

These results suggest that the developed digital worksheet is suitable for use in mathematics learning to foster students' computational thinking and contextual problem-solving skills, and future studies are recommended to examine its effectiveness across larger and more diverse samples as well as its integration into various classroom contexts to further support meaningful and sustainable learning outcomes.

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