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Integrating Geogebra and Liveworksheets in Developing PMRI-Based Interactive Worksheets: a 4D Model Study on Linear Equations

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Abstract

To address persistent shortcomings in students' conceptual understanding, this development study designed and validated interactive digital worksheets grounded in the Indonesian Realistic Mathematics Education approach (PMRI) and integrating GeoGebra and Liveworksheets for eighth-grade instruction on linear equation. Employing the 4D model (Define–Design–Develop–Disseminate), data were collected through expert validation sheets, student response questionnaires in small- and large-group trials, and interviews; quantitative data were analyzed descriptively (percentages) and complemented by qualitative analysis. The worksheets received ratings of 93.71% from material and language experts, 85.49% from media experts, and 98% from practitioner experts, while student practicality ratings averaged 88.93% (small group) and 91.88% (large group), yielding an overall mean of 91.56%. These findings indicate that the PMRI-based interactive digital worksheets are valid and practical for classroom use on linear equations in grade 8 and are ready for dissemination; future studies should examine their effectiveness for improving learning outcomes using comparative or experimental designs.

Keywords: GeoGebra; Interactive digital worksheets; Liveworksheets; 4D model; PMRI.

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INTRODUCTION

Mathematics is a universal discipline that plays a fundamental role across fields of study and in everyday life. Mastery of mathematics not only supports understanding of other disciplines, but also cultivates logical, systematic, and critical thinking. According to Rambe (2023), many students still perceive mathematics as difficult and tedious, which decreases their motivation to learn; this negative perception leads to low learning outcomes and limited student engagement (Oktavia & Hidayati, 2022). Consistently, Syahri (2014) emphasizes that students' perceptions of mathematics and teacher competence significantly influence learning achievement; instruction should therefore be designed to be more engaging and meaningful, and to foster positive attitudes toward mathematics.

Within Indonesia's Merdeka Curriculum, mathematics is a core subject in Phase D (lower secondary school). A key topic at this level is the equation of a linear equations, which underpins the mastery of subsequent concepts and serves as a vehicle for developing higher-order thinking skills (Putra, 2016). However, a preliminary study at SMP Negeri 7 Jakarta indicated that many eighth-grade students struggle to understand both the concept and the application of linear equations; they tend to memorize formulas without grasping their conceptual meaning. This finding aligns with Hakim and Aji (2020), who reported that weak conceptual understanding leads to errors in solving problems on linear equations and reduces students' interest in continuing to study mathematics.

Interviews with the school's mathematics teacher revealed that instruction remains teacher-centered and that instructional media are not yet optimally utilized. In fact, learning media play an important role in helping students comprehend abstract concepts (Ningrum et al., 2023). One medium that can enhance. the effectiveness of learning is the student worksheet (*lembar kerja peserta didik*, LKPD). Talo et al. (2022) assert that LKPDs can guide exploration, investigation, and independent problem solving, thereby cultivating critical, creative, and collaborative thinking.

In line with technological developments in the Industry 4.0 era, integrating technology into instruction has become essential. Interactive digital LKPDs have the potential to increase students' motivation and engagement. Ningrum et al. (2023) found that learners are more attracted to lessons that incorporate audio, video, and animation. The Liveworksheets platform supports the development of interactive digital LKPDs through features such as drag-and-drop items, audio, and automatic correction, thereby providing immediate feedback and a more immersive learning experience.

Nevertheless, technology alone does not guarantee conceptual understanding if the pedagogical approach is not contextualized. *Pendidikan Matematika Realistik Indonesia* (PMRI)—the Indonesian adaptation of Realistic Mathematics Education (RME)—is relevant because it emphasizes connecting mathematical concepts to real-world situations so that learning becomes more meaningful (Sari, 2017; Purba et al., 2022). Through PMRI, students are encouraged to construct concepts for themselves using familiar contexts, which is compatible with the procedural and abstract nature of linear equations; accordingly, instruction should begin with contextual problems (Ayu Anggraini & Kristanto, 2022).

Moreover, GeoGebra strengthens visualization and enables students to relate equations to straight-line graphs through dynamic exploration on computers or mobile devices. Manalu et al. (2019) reported that using GeoGebra makes mathematics learning more engaging and less monotonous. Furthermore, a study by Birgin and Uzun Yazici (2021) with eighth-grade students showed that GeoGebra-assisted mathematics instruction significantly improves conceptual understanding and retention on the topics of linear equations and slope compared with direct, textbook-based instruction. Based on this rationale, the present study aims to develop and evaluate the feasibility of an interactive digital LKPD grounded in PMRI and supported by GeoGebra, implemented through the Liveworksheets platform, for teaching linear equations to eighth-grade students. The product is expected not only to enhance students' conceptual understanding but also to support teachers in delivering mathematics instruction that is engaging, interactive, and contextual

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METHOD

Setting and Timeframe

This study was conducted at SMP Negeri 7 Jakarta, located at Jl. Balai Rakyat, Kelurahan Utan Kayu Utara, Kecamatan Matraman, East Jakarta, DKI Jakarta. The research was conducted through several stages, including needs analysis, design, development, expert validation, try-out, revision, and initial dissemination. The needs analysis was conducted in December 2024 and involved eighth-grade students and a mathematics teacher during the odd semester of the 2024/2025 academic year. The product development, expert validation, and revision stages were conducted subsequently, followed by small-group and large-group try-outs in August–September 2025 with eighth-grade students during the odd semester of the 2025/2026 academic year. The final product was then disseminated at an initial/local level after the development and try-out stages were completed.

Research Design and Procedure

This research employed a Research and Development (R&D) approach using the 4D model (Define, Design, Develop, Disseminate) developed by Thiagarajan, Semmel, and Semmel (1974). The 4D model was chosen because it provides a systematic pathway for developing instructional media, from needs identification to product dissemination.

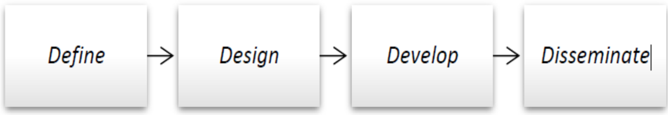

Figure 1. Steps in the 4D Model

Define. This stage focused on identifying needs and problems in mathematics instruction, particularly on the topic of linear equations. Data were collected through (a) a student needs-analysis questionnaire, (b) semi-structured interviews with the mathematics teacher, and (c) direct classroom observations. A literature review was also conducted on Pendidikan Matematika Realistik Indonesia (PMRI), which emphasizes linking mathematical concepts to real-life contexts (Van den Heuvel-Panhuizen, 2003).

Design. This stage produced the product specifications and the initial prototype of an interactive digital student worksheet (LKPD) based on PMRI and integrated with GeoGebra and Liveworksheets. *Canva for Education* was used for visual design; GeoGebra supported dynamic graphical activities (e.g., exploration of slope and the general form of a linear equation); and Liveworksheets functioned as the online interactive platform (drag-and-drop, fill-in items, and automated feedback). The activity scenarios foregrounded PMRI characteristics—context → model → symbolization—along with interactivity and active student engagement.

Develop. Content, language, and media experts validated the prototype. Validation assessed content accuracy, language clarity, and the attractiveness and consistency of the interface. Feedback from validators was incorporated into revisions until the media were deemed ready for try-out. The try-outs were administered twice: a small-group test (10 students) and a large-group test (30 students) to evaluate practicality, comprehensibility, and students' responses to the interactive digital LKPD.

Disseminate. The finalized product was disseminated via the Liveworksheets platform. Access links were shared with mathematics teachers at SMP Negeri 7 Jakarta so that the LKPD could be used more broadly as an alternative instructional medium.

Instrument

Data were collected using several instruments to obtain a comprehensive picture of the phenomenon under study. A student needs-analysis questionnaire was administered; an in-depth, semi-structured interview with the mathematics teacher was conducted to elicit details of grade-VIII mathematics instruction; and classroom observations of grade-VIII mathematics lessons at SMP Negeri 7 Jakarta documented the instructional methods/models employed, the learning media used, and student characteristics. Expert-validation questionnaires were then used to evaluate the instructional media prior to implementation, involving both content–language experts and media experts.

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Practicality was measured through teacher and student response questionnaires to the LKPD. The content–language experts assessed the suitability and accuracy of the content; alignment with the PMRI approach (its characteristics and principles); presentational feasibility (technique, supporting elements, and completeness); and the clarity and correctness of language as well as its appropriateness for students' cognitive levels. Media experts examined appearance and functionality, including design consistency, readability, layout, image visualization, and overall attractiveness of the interactive LKPD. The teacher response questionnaire consisted of four domains—appearance (4 items), content (7 items), instruction/implementation (2 items), and interactivity & ease of use (4 items)—whereas the student response questionnaire comprised five domains: appearance & design (4 items), content quality (4 items), learning (4 items), interactivity & engagement (2 items), and ease of use (3 items).

Data Analysis

Data analysis included validity and practicality evaluations. The validity analysis determined the appropriateness of the developed product. Teachers and students completed practicality questionnaires to capture their responses to the PMRI-based digital LKPD. All ratings used a Likert scale and were converted into percentages for interpretation. The interpretation criteria were as follows:

Table 1. Criteria for Media Validity

Interval	Category
$0\% < P \leq 20\%$	Not Valid
$20\% < P \leq 40\%$	Less Valid
$40\% < P \leq 60\%$	Fairly Valid
$60\% < P \leq 80\%$	Valid
$80\% < P \leq 100\%$	Highly Valid

(Riduwan & Sunarto, 2019)

Table 2. Criteria for Media Feasibility

Interval	Category
$0\% \leq P \leq 20\%$	Highly Inappropriate
$20\% < P \leq 40\%$	Inappropriate
$40\% < P \leq 60\%$	Fairly Appropriate
$60\% < P \leq 80\%$	Appropriate
$80\% < P \leq 100\%$	Highly Appropriate

(Riduwan & Sunarto, 2019)

The criteria in the tables above were used to determine the validity and feasibility of the instructional media for classroom use

RESULTS AND DISCUSSION

The results of this study produced a valid and feasible interactive digital student worksheet (LKPD) on the topic of *Linear Equations* using the Indonesian Realistic Mathematics Education (PMRI) approach, assisted by GeoGebra and developed through Liveworksheets. The development process followed the 4D model (Define, Design, Develop, and Disseminate) proposed by Thiagarajan et al. (1974).

Define Stage

The *Define* stage is the initial step in the development research, aiming to obtain comprehensive information regarding the learning problems experienced by both teachers and students. This stage consisted of three main components: needs analysis, material analysis, and literature review.

The results of the needs analysis revealed that eighth-grade students encountered difficulties in understanding concepts, formulas, and real-life applications of *linear equations*. These findings are consistent with Oktavia and Hidayati (2022), who reported that students' negative perceptions of mathematics often arise from monotonous learning activities that lack contextualization. Most respondents expressed a strong need for interactive digital learning media. The teachers' interviews

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confirmed this, emphasizing the necessity of technology-assisted learning media to improve students' engagement and understanding.

This aligns with Puspitasari and Rayungsari (2024), whose *systematic literature review* concluded that technology-based learning media significantly enhance students' motivation and interest in mathematics. Therefore, the development of interactive digital worksheets becomes highly relevant to support 21st-century learning demands.

Design Stage

The *Design* stage was carried out to provide a comprehensive representation of the structure and content of the developed worksheet. The design process included creating a storyboard, preparing content, and designing the media layout. Canva was used to design the visual layout of the worksheet, GeoGebra was used to create interactive learning activities, and Liveworksheets served as the main platform for compiling the digital worksheet.

According to Gurmu et al. (2024), the integration of GeoGebra in mathematics education effectively enhances students' conceptual understanding and visual reasoning abilities. Thus, the use of GeoGebra in this research is appropriate for the topic of linear equations, which requires visual representations to explain the concept of slope and linearity.

In addition, the expert validation sheets and response questionnaires were systematically designed based on established principles of content validity. Expert validation data were analyzed using Lawshe's (1975) Content Validity Ratio (CVR), supported by the content validity index (CVI) approach of Polit and Beck (2006**.** Meanwhile, responses from the Likert-scale questionnaires were converted into percentages to determine the level of students' and teachers' responses to the developed digital worksheet.

Develop

The *Develop* stage aimed to transform the design into a functional and validated digital worksheet. The final product consisted of key components such as a cover page, editorial page, concept map, learning obje ctives, and usage instructions, all designed to guide students toward independent use.

Figure 1. Front Cover of LKPD

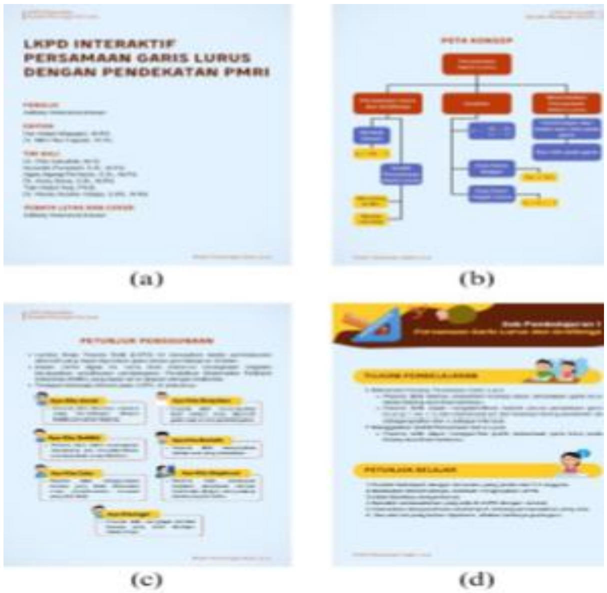

Figure 2. Editorial page, concept map, user guide and learning objectives.

Figure 1 shows the front cover of the digital student worksheet (LKPD). The cover displays two logos: the logo of *Universitas Negeri Jakarta (UNJ)* and *Tut Wuri Handayani*. It also includes information about the implemented curriculum, namely the *"Kurikulum Merdeka"*, the product title *"LKPD (Student Worksheet)"*, the main topic *"Linear Equations"*, and the subtopics *"Linear*

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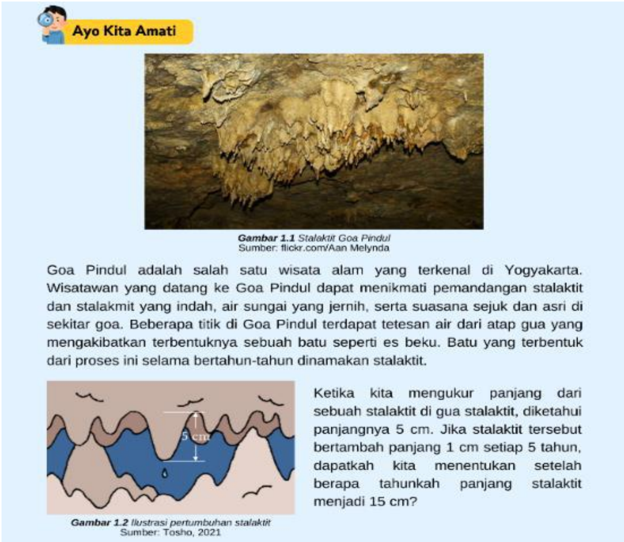
Equations and Their Graphs," "Slope of a Line," and *"Determining the Equation of a Line."* The adopted learning approach is *"Based on the PMRI (Indonesian Realistic Mathematics Education) Approach."* The target users are *Grade VIII Junior High School students*, and the cover provides space for student identity, including *Name, Class, and School.*

Figure 2 part (a) presents the editorial page, which includes the title of the digital LKPD, the list of authors, editors, expert team, as well as layout and cover designers. Part (b) displays the concept map of the *Linear Equation* topic. Part (c) contains the user guide page, providing instructions for students on how to use the digital LKPD. Part (d) presents the learning objectives and study guidelines page.


Ayo Kita Amati

Gambar 1.1 *Stalaktit Goa Pindul*
Sumber: flickr.com/Aan Melynda

Goa Pindul adalah salah satu wisata alam yang terkenal di Yogyakarta. Wisatawan yang datang ke Goa Pindul dapat menikmati pemandangan stalaktit dan stalakmit yang indah, air sungai yang jernih, serta suasana sejuk dan asri di sekitar goa. Beberapa titik di Goa Pindul terdapat tetesan air dari atap gua yang mengakibatkan terbentuknya sebuah batu seperti es beku. Batu yang terbentuk dari proses ini selama bertahun-tahun dinamakan stalaktit.

Ketika kita mengukur panjang dari sebuah stalaktit di gua stalaktit, diketahui panjangnya 5 cm. Jika stalaktit tersebut bertambah panjang 1 cm setiap 5 tahun, dapatkah kita menentukan setelah berapa tahunkah panjang stalaktit menjadi 15 cm?

Gambar 1.2 *Ilustrasi pertumbuhan stalaktit*
Sumber: Tosho, 2021

Figure 3. Characteristics of Learning Activity Contexts in the PMRI Approach

Figure 3. Learning activities using the PMRI approach presented in this digital worksheet begin with real-world problems, after which students discover informal solutions such as models, drawings, sketches, or patterns. Subsequently, students develop a deeper understanding of mathematical ideas, including formulas and concepts.

4. Misalkan panjang stalaktit setelah x tahun adalah y cm, lengkapilah tabel berikut dan tentukan dalam berapa tahun stalaklit menjadi 15 cm?

***x* (tahun)**	0	5	10	15	20	25	30	35	40	45	50
***y* (cm)**	5	6	7								

Stalaklit akan menjadi 15 cm saat ..... tahun.

5. Jika kamu masukkan data dari tabel sebagai titik-titik pada bidang koordinat kartesius, kemudian kamu hubungkan titik-titik nya, bagaimana bentuk grafik tersebut?

Petunjuk: kamu bisa gunakan bantuan GeoGebra untuk menjawab pertanyaan ini dengan mengunjungi tautan berikut

Materi Persamaan Garis Lurus

Figure 4. Characteristics of Using Models in Learning Activities within the PMRI Approach

Figure 4 illustrates the characteristics of using models in the subtopic of linear equations and their graphs. The process of observing and recording stalactite growth data is referred to as the *"model of"* stage. To progress to the *"model for"* stage, students must transform the collected data into graphical representations and subsequently derive the definition of a linear equation.

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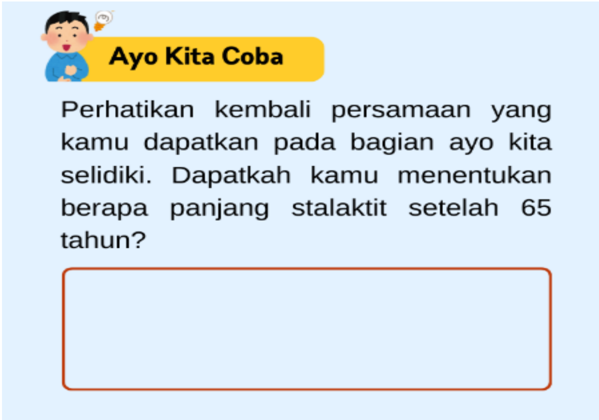

Figure 5. Characteristics of Student Participation in Learning Activities within the PMRI Approach

Figure 5 illustrates the characteristic of student participation in the digital worksheet. After students successfully construct mathematical models, namely formulas from several subtopics of the linear equation material, they can then apply these formulas and modify them based on their own ideas, reasoning, or strategies to solve other related problems within the same topic.

Figure 6. Characteristics of Interactivity in Learning Activities within the PMRI Approach

Figure 6 illustrates the interaction between students and the product, as evidenced by their direct engagement with GeoGebra, which enables them to explore mathematical concepts both visually and practically.

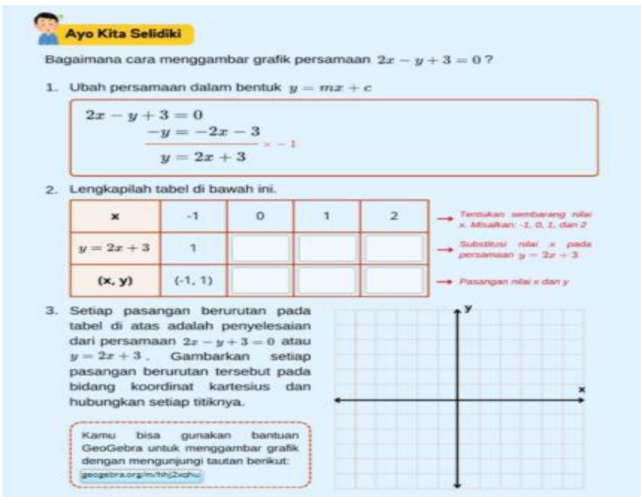

Figure 7. Characteristics of Interconnectedness Between Topics in Learning Activities within the PMRI Approach

Figure 7 illustrates students' activities in drawing the graph of a linear equation. Constructing a linear graph requires an understanding of the Cartesian coordinate system, which involves knowledge

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of the x- and y-axes, points on the plane, and the process of plotting and connecting these points to form a linear equations. Thus, the topic of the Cartesian coordinate system is closely related to the concept of linear equations.

The interactive nature of the worksheet built using Liveworksheets and GeoGebra was expected to increase students' active engagement and conceptual understanding. Juandi et al. (2021) conducted a meta-analysis confirming that GeoGebra-assisted learning over the past decade has significantly improved students' learning outcomes and motivation in mathematics.

Similarly, Siregar (2025) found that interactive worksheets developed through Liveworksheets demonstrated high expert validation scores—91.67% for content validity and 92.59% for media validity—categorized as "highly feasible." These findings corroborate the present study's validation results, where expert judgments from content and language validators yielded an average score of 93.71% (very valid), while media validation achieved 85.49% (very valid).

Experts suggested improvements related to color contrast, font consistency, and mathematical notation alignment with academic standards. This corresponds to Wassie (2019), who emphasized that while GeoGebra promotes interactivity, the effectiveness of digital learning media also relies heavily on aesthetic design and user interface quality.

Furthermore, the integration of PMRI principles in this worksheet facilitates students' progression from contextual understanding (*model of*) to formal abstraction (*model for*), as described by Van den Heuvel-Panhuizen (2003). Consequently, students construct their own mathematical understanding through modeling and visual exploration, rather than rote memorization of formulas.

Disseminate

After the media development stage produced the final product, the next stage was the dissemination phase. At this stage, the developed interactive digital worksheet was disseminated at an initial/local level by publishing the product through the Liveworksheets platform. Access to the interactive digital student worksheet (LKPD) was provided through a Linktree link, which was then shared with mathematics teachers of eighth-grade students at the research site. This initial dissemination was intended to provide access to the developed product for use in the learning context of the research site.

The interactive digital worksheet was subsequently implemented in classroom learning on the topic of *Linear Equations*. This implementation was conducted to observe the use of the developed product in the actual learning context and to obtain students' responses to its use. The implementation procedure was as follows: (1) before beginning the lesson on *Linear Equations*, the teacher shared the interactive digital worksheet link with students through a WhatsApp group; (2) during the learning process, the teacher implemented the PMRI-based instructional steps provided in the worksheet, including: (a) understanding contextual problems, in which the teacher reviewed the contextual problems presented in the *"Let's Observe"* section of the interactive digital worksheet and facilitated a discussion to help students identify key ideas within the problem. This stage encouraged students' contributions, representing one of the key characteristics of the PMRI approach; (b) solving contextual problems, in which the teacher guided students in solving the contextual problems using their own responses as a foundation to build mathematical models and derive solutions. The teacher utilized the sections *"Let's Investigate," "Let's Try,"* and *"Let's Explore"* contained in the interactive digital worksheet; (c) comparing and discussing solutions, in which the teacher invited students to compare their answers with those of their peers to foster collaborative reasoning and reflection; and (d) drawing conclusions, in which the teacher encouraged students to independently formulate conclusions based on their learning outcomes after completing the activities in the *"Let's Conclude"* section of the interactive digital worksheet.

This implementation was designed to support meaningful mathematics learning by providing students with opportunities to construct mathematical understanding through contextual situations and discussion. Such an approach is consistent with the principles of PMRI, which emphasize students' active involvement in constructing mathematical ideas from meaningful contextual experiences rather than relying primarily on rote memorization, as emphasized by Juandi et al. (2021) and Van den Heuvel-Panhuizen (2003).

CONCLUSION

Based on the findings of the development study, the interactive digital worksheet integrating the PMRI approach and supported by GeoGebra through Liveworksheets was successfully developed to support the learning of linear equation concepts among eighth-grade junior high school students. The developed digital worksheet obtained an overall average score of 91.56%, indicating a very feasible level of feasibility based on the validation results. The product also received positive responses from students, indicating that it was practical and could be used as a learning resource in mathematics instruction. These findings indicate that the developed digital worksheet has demonstrated feasibility and practicality for supporting the learning process of linear equations. However, its effectiveness in improving students' mathematical understanding, problem-solving skills, or engagement has not yet been empirically tested in this study. Therefore, further research is recommended to examine the effectiveness of the digital worksheet through appropriate experimental or quasi-experimental studies. Future studies may also investigate its implementation across different mathematical topics, learning contexts, and broader student populations.

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