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Development of a Scratch-Based Digital Worksheet to Support Deep Learning on the Topic of Scale

Fransisco Danil C.[1], Zulkardi[2], Budi Mulyono[3]
[1, 2, 3] Department of Mathematics Education, University of Sriwijaya
***Corresponding author, e-mail: fransiscodanil@gmail.com**

Abstract

This study aims to develop a digital Student Worksheet (LKPD) assisted by Scratch on the topic of scale using a digital map context that is valid and practical. The research employed a design research methodology of the development studies type, consisting of three stages: preliminary research, development or prototyping phase, and assessment phase. The validation stage was carried out by experts through an expert review to evaluate the content, construct, language, and technology aspects. Meanwhile, practicality was obtained from students' responses during the small group phase after using the digital LKPD in learning activities. The results show that the Scratch-assisted digital LKPD achieved an average validity level of 92.47% (categorized as very valid) and a practicality level of 83.12% (categorized as practical). Thus, the Scratch-assisted digital LKPD developed in this study is considered valid and practical for use in mathematics learning on scale, and it has the potential to support students' deep learning through contextual activities based on digital maps.

Keywords: Digital Worksheet, Scratch, Scale, Digital Map, Deep Learning

INTRODUCTION

Mathematics is a discipline that plays a fundamental and irreplaceable role in cultivating students' logical, critical, analytical, and systematic thinking abilities. As a foundational science, mathematics contributes not only to students' cognitive development but also to their capacity to navigate real-life challenges that require reasoning and decision-making. The essence of mathematics extends far beyond performing calculations; it involves building conceptual understanding, recognizing relationships, and interpreting quantitative information in meaningful ways (Safari & Nurhida, 2024). Ideally, learning experiences should be designed to be engaging, contextual, and capable of encouraging students to actively construct knowledge. However, classroom practices still largely rely on conventional worksheets that are static, text-heavy, and procedural. Such tools often fail to stimulate higher-order thinking or support students in developing deep conceptual structures, ultimately resulting in passive learning and limited exploration of mathematical ideas (Meka et al., 2024).

At the same time, Indonesia is experiencing a significant and rapid rise in digitalization across various sectors. National statistical data (BPS, 2019-2024) reveal a substantial increase in internet penetration, from 47.69% to 72.78% within five years, illustrating a transformation in how society accesses information and interacts with digital environments. This trend is further strengthened by Komdigi's report indicating that by early 2024, approximately 79.5% of the population-equivalent to 221.6 million individuals-were active internet users. Such developments signal a shift in learning

preferences, access to digital tools, and the technological readiness of students, many of whom are now categorized as digital natives. Consequently, integrating digital media into classroom practices is no longer optional but imperative, ensuring that instructional approaches align with students' digital habits and prepare them for future academic and societal demands.

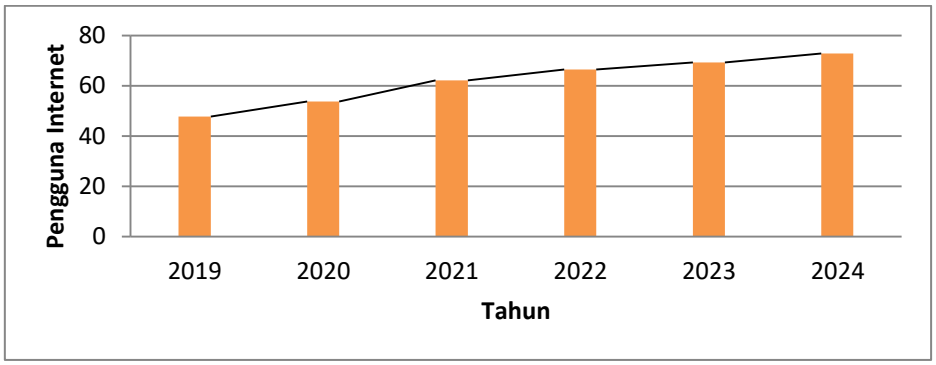

Figure 1. Internet User Data in Indonesia 2019–2024 (in %)

This urgency becomes even more pronounced in the context of Grade VII mathematics, particularly in the study of ratios, which serves as the conceptual foundation for comparison, proportion, and scale. Despite the centrality of ratio concepts in mathematics, research consistently shows that students often struggle to internalize proportional reasoning. They tend to rely on additive rather than multiplicative strategies, leading to persistent misconceptions and incorrect interpretations of proportional relationships. The topic of scale-one of the most tangible applications of ratio-exemplifies this challenge. Many students interpret scale merely as a formula to be memorized, neglecting the deeper conceptual link between maps and real-world distances (Anzani, 2024). Such superficial understanding is exacerbated by instructional practices that prioritize formulaic procedures over exploration and contextual reasoning. Studies by Puteri & Mariana (2024) and Kurniawan et al. (2023) further demonstrate that when learning emphasizes rote memorization, students struggle to transfer knowledge to real-life settings, resulting in a disconnect between mathematical ideas and authentic problem-solving.

To overcome these learning barriers, instruction must shift toward deep learning-a pedagogical paradigm that emphasizes thoughtful engagement (mindful), meaningful connections among concepts (meaningful), and enjoyable learning experiences (joyful) (Kemendikdasmen, 2024). Deep learning encourages students to reflect, make sense of mathematical relationships, and construct knowledge in a way that leads to durable understanding. Within this framework, learners are guided to see scale not simply as a ratio stated symbolically, but as a meaningful representation of spatial relationships in real contexts. By fostering opportunities for inquiry, guided reinvention, and conceptual coherence, deep learning becomes a powerful approach to addressing students' misconceptions and strengthening their proportional reasoning.

Advancements in educational technology provide promising opportunities to promote deep learning through interactive and dynamic media such as Scratch. Scratch serves as a highly accessible programming platform that enables the creation of visual simulations, animations, and interactive tools. In the context of scale, students can manipulate digital rulers, measure map segments, and observe how distances relate to real-world representations. These interactive features support conceptual exploration, promote active engagement, and enable students to visualize abstract relationships more

concretely (Sholeh et al., 2022; Naim et al., 2025). Prior research demonstrates that the use of Scratch enhances academic achievement, spatial reasoning, creativity, and student motivation more effectively than conventional instructional methods (Al-Otaibi et al., 2023; Gotama, 2024; Said, 2023). Despite these advantages, the integration of Scratch into Digital Worksheets-particularly when combined with digital-map contexts-remains underexplored in mathematics education, leaving a gap that warrants investigation.

Given these circumstances, there is a compelling need to develop an innovative learning tool in the form of a Scratch-assisted Digital Worksheet linked to digital maps. Such a tool has the potential to bridge conceptual gaps by enabling students to experience scale as a meaningful representation of spatial relationships rather than as an abstract ratio. By situating learning within authentic, visually supported contexts, the digital worksheet can enhance engagement, foster deeper understanding, and encourage students to develop proportional reasoning skills more effectively. Therefore, this study is pivotal in addressing the demand for interactive, contextual, and pedagogically robust learning media capable of promoting deep learning in mathematics classrooms.

METHODS

The research method employed in this study is design research of the development studies type, which follows three main phases: preliminary research, development or prototyping phase, and assessment phase (Plomp, 2013). This study focuses on the development and iterative testing of a Scratch-assisted Digital Worksheet up to the small-group stage in order to evaluate the product's validity and practicality.

The research subjects consisted of Grade VII students from a lower secondary Islamic school (MTs). The research procedure was organized into two major components: (1) preliminary analysis and initial product design, and (2) prototype development through successive stages of formative evaluation.

Preliminary Research. This phase involved a comprehensive needs analysis, curriculum analysis, and examination of student characteristics relevant to the learning of scale. In addition, key concepts of deep learning-mindful, meaningful, and joyful learning-were reviewed to determine how they would be integrated into the Digital Worksheet. The analysis also included an exploration of digital-map contexts as the starting point for problem situations, as well as an examination of the potential of Scratch as an interactive medium for the scale topic. The results of this phase provided the foundation for designing the overall structure of the Digital Worksheet, the sequence of learning activities, and the Scratch-based simulations intended to support conceptual exploration.

Development or Prototyping Phase. This phase consisted of four main activities: self-evaluation, expert review, one-to-one evaluation, and small-group evaluation. These stages were conducted iteratively to refine the product from Prototype I to Prototype III. Each stage served a distinct function in the improvement process: self-evaluation allowed the researcher to revise the initial design; expert review provided professional validation regarding content, construct, language, and ICT aspects; one-to-one sessions captured students' initial responses and usability issues; and small-group testing facilitated the assessment of practicality and the product's potential to support deep learning in a more authentic classroom setting.

a. Self-Evaluation

The initial design of the Digital Worksheet was carried out by the researcher through a careful review of the coherence of the activity flow, the clarity and usability of the interface, the integration of Scratch-based components, and the alignment with deep

learning indicators. At this stage, the researcher refined several design elements, including color schemes, layout structure, interactive icons, user instructions, and the configuration of Scratch simulations-such as zooming in and out of the map and measuring distances along digital routes. This internal evaluation process resulted in Prototype I of the Scratch-assisted Digital Worksheet.

b. Expert Review

This stage involved a panel of experts consisting of two mathematics education lecturers and one educational technology lecturer. The experts evaluated three major aspects of the product: Content, Language, and Media (ICT). The validation instrument employed a five-point rating scale, with categories presented in Table 1. During this stage, the experts examined the conceptual accuracy of the material, the clarity and appropriateness of the language used, and the technical quality and functionality of the digital and Scratch-based components. Their feedback served as the basis for revising and improving the worksheet design prior to subsequent evaluation stages.

Table 1. Rating Categories for the Expert Validation Sheet

Score	Category
5	Excellent
4	Good
3	Fair
2	Poor
1	Very Poor

(Mukti, 2022)

Validity was calculated using the following formula:

$$Validity\ Percentage = \left(\frac{Score\ Obtained}{Maximum\ Score}\right) \times 100\%$$

The resulting percentage was then classified according to the criteria presented in Table 2.

Table 2. Validity Criteria

Score	Category
85.1% – 100%	Very Valid
70.1% – 85%	Valid
50.1% – 70%	Fairly Valid
0.1% – 50%	Not Valid

(Mukti, 2022)

The revisions obtained from the expert review resulted in Prototype II.

c. One-to-One

This stage involved three students representing high, medium, and low ability levels. Each student was asked to complete a portion of the activities in the Digital Worksheet to examine several aspects: the clarity of instructions, the coherence of the task sequence, the ease of operating Scratch components, the readability of the language, and the alignment of the activities with deep learning indicators. Feedback from the students was used to refine the visual layout, instructional wording, and navigation flow of the worksheet. The revisions made at this stage produced Prototype III.

d. Small Group

The small-group stage involved six students, divided into two groups of three. Students worked collaboratively to complete the Digital Worksheet activities while the researcher observed several dimensions: ease of use, clarity of instructions, the relevance

of activities to the digital-map context, the usefulness of Scratch simulations, and the extent to which the learning experience supported deep learning. After completing the activities, students filled out a practicality questionnaire using a Likert scale, as presented in Table 3.

Table 3. Scoring Guidelines for the Practicality Questionnaire

Statement Type	SA	A	NA	D	SD
Positive	5	4	3	2	1
Negative	1	2	3	4	5

SA = Strongly Agree, A = Agree, NA = Neutral/Somewhat Agree, D = Disagree, SD = Strongly Disagree

The practicality percentage was calculated using the following formula:

$$Practicality\ Percentage = \left(\frac{Score\ Obtained}{Maximum\ Score}\right) \times 100\%$$

The practicality category was then determined based on the criteria presented in Table 4.

Table 4. Practicality Criteria

Percentage	Category
85%–100%	Very Practical
70%–84%	Practical
56%–69%	Less Practical
40%–55%	Not Practical
< 40%	Very Impractical

The results of this stage served as the basis for determining the feasibility of Prototype III before proceeding to the final phase.

RESULTS AND DISCUSSION

Preliminary Research Phase

In the preliminary research phase, a needs analysis and initial product design were conducted as the foundation for developing the Scratch-assisted Digital Worksheet. The needs analysis began with an interview with a Grade VII mathematics teacher to identify learning conditions related to the use of digital media, students' understanding of the concept of scale, and the extent to which deep learning principles had been implemented in the classroom. The interview results indicated that scale instruction was still carried out using conventional, static worksheets, and that the use of digital media-including Scratch-had never been applied. The teacher reported that students tended to memorize scale formulas without understanding their connection to real-world contexts, particularly in interpreting or reading digital maps. This situation also resulted in the suboptimal development of mindful, meaningful, and joyful learning components.

Based on these findings, the researcher conducted a further analysis of the curriculum, the characteristics of the scale topic, common student errors, and teachers' needs for more interactive learning media. Curriculum analysis confirmed that the topic of scale is part of the Ratio chapter in the Merdeka Curriculum, making proportional reasoning an essential conceptual foundation before students learn scale. However, field observations showed that many students struggled to relate numerical representations on a map to actual distances due to limited exploratory learning experiences.

Next, the researcher analyzed the potential of digital-map contexts as the starting point for learning activities. Digital maps were selected because they are closely related

to everyday life and allow students to measure and compare distances more concretely. The use of Scratch was examined as a tool for creating visual simulations-such as zooming in, zooming out, and dragging maps-that support a more dynamic and interactive understanding of scale. The integration of Scratch also aimed to foster a more joyful learning atmosphere through animation and visual movement.

In addition, the researcher prepared research instruments, including validation sheets covering content, construct, language, and ICT aspects, as well as a deep learning observation sheet that measured the three main components: mindful, meaningful, and joyful learning. These instruments were used to ensure that the developed worksheet met content feasibility standards while also promoting richer learning experiences.

The preliminary research phase then continued with the initial design of the Scratch-assisted Digital Worksheet. This design included developing activities based on digital-map contexts, providing Scratch simulations for distance and scale exploration, and structuring the learning flow from concrete–model–formal in accordance with PMRI pedagogical principles and guided reinvention strategies. This initial design served as the foundation for producing Prototype I of the Scratch-assisted Digital Worksheet, which would be evaluated in the subsequent phase.

Development or Prototyping Phase

a. Self-Evaluation

In the self-evaluation stage, the researcher conducted an initial review of the Scratch-assisted Digital Worksheet design that had been developed based on the results of the preliminary research. This activity included examining the alignment of the activity sequence with the learning objectives of the scale topic, the integration of the digital map context, and the application of deep learning indicators (mindful, meaningful, joyful) in each section of the worksheet.

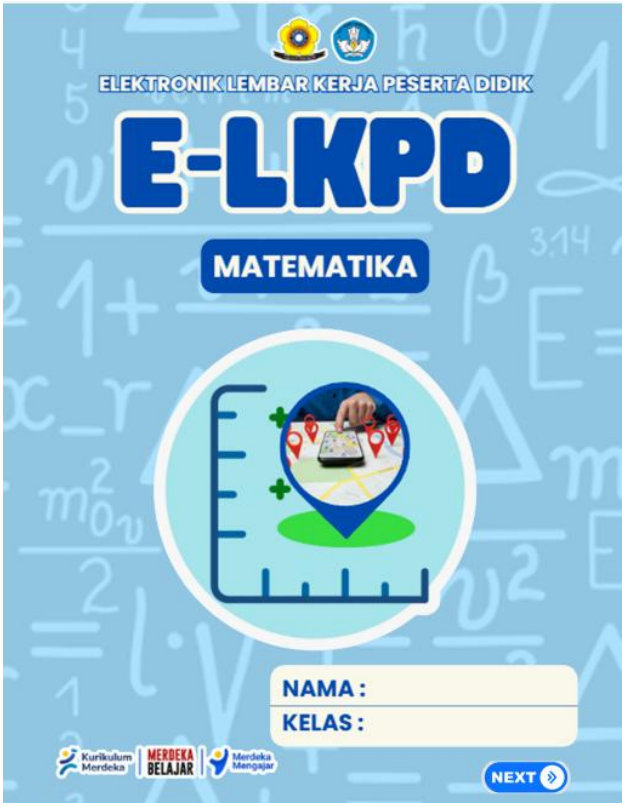

Figure 2. Initial display of the Digital Worksheet homepage

Technically, the researcher refined the interface design of the Digital Worksheet to ensure greater consistency and ease of navigation for students. Adjustments were made to color selection, icon design, font size, and the placement of navigation buttons (next, back, home) to create a clearer workflow throughout the worksheet. At this stage, the researcher also configured the scenarios for using Scratch as the primary interactive medium, such as zooming in and out of the map, dragging the map to different positions, and measuring distances between two points on the digital map.

In addition, the researcher reviewed the wording of instructions in each activity to align with mindful learning principles-ensuring clarity, guidance, and opportunities for reflection-while also verifying that the digital map contexts used were genuinely relevant to real-life situations that students may encounter. The self-evaluation process resulted in Prototype I of the Scratch-assisted Digital Worksheet, which was then ready for expert validation.

Figure 3. Initial Design of the Activity Sheet in the Digital Worksheet

b. Expert Review

The expert review stage was conducted to assess the validity of the Scratch-assisted Digital Worksheet in terms of content, construct, language, and technology (ICT). The panel of validators consisted of two mathematics education lecturers, one educational technology lecturer, and one mathematics teacher with extensive experience teaching the topic of scale. The experts were asked to examine the worksheet using the validation sheet and to provide written comments and suggestions for improvement. Based on the results of the expert review, the researcher made revisions to the task content, map contexts, button layout, and explanations of key terms. After the revisions were completed, the validators re-evaluated the worksheet by completing the validation sheet once more. A summary of the validity results is presented in Table 5.

Table 5. Validity Results of the Scratch-Assisted Digital Worksheet

Aspect	Percentage	Category
Content	94.10%	Very Valid
Language	90.10%	Very Valid
ICT	92.50%	Very Valid
Average	92.47%	Very Valid

The results in Table 6 indicate that the Scratch-assisted Digital Worksheet achieved an average validity score of 92.47%, categorized as very valid. Specifically, the content aspect scored above 93%, suggesting that the materials, activity sequence, and alignment with the digital-map context were consistent with curriculum requirements and learning objectives. The language and ICT aspects also received very valid ratings, indicating that the instructions were considered clear and easy to understand, and that the integration of Scratch was deemed appropriate and supportive of the learning process.

c. One-to-One

The one-to-one stage was carried out in parallel with the expert review to observe how students interacted directly with Prototype II of the Scratch-assisted Digital Worksheet. Three students were selected based on recommendations from the mathematics teacher, representing high, medium, and low ability levels. The students were asked to complete a portion of the worksheet activities while verbalizing any difficulties they encountered. The main findings from the one-to-one stage are summarized in Table 6.

Table 6. Findings from the One-to-One Stage and Follow-Up Actions

No	Student Comments	Revision Decisions
1	Students had difficulty understanding the initial steps of using Scratch (e.g., which button to click first).	Added a brief guide with numbered steps and arrow icons on the instruction page.
2	Students were confused about distinguishing "distance on the map" and "actual distance" in one activity.	Added a comparison illustration and a simple numerical example before the main problem.
3	Students felt that the allotted time was insufficient for reading the map, measuring distances, and answering items.	Added estimated completion time information for each activity and clarified task boundaries.

Based on the table above, the revisions focused on simplifying the operational instructions for using Scratch, clarifying the conceptual distinction between map distance and actual distance, and adjusting the time-related indicators for task completion. After these improvements, Prototype III was considered easier to use by students with varying ability levels.

d. Small Group

The small-group stage was conducted to examine the practicality of the Scratch-assisted Digital Worksheet in a learning situation that more closely resembles actual classroom conditions. Six students were divided into two small groups, each consisting of three members. They were instructed to complete the full sequence of activities in the Digital Worksheet while the researcher acted as an observer.

After completing the activities, the students were asked to fill out a practicality questionnaire covering four aspects: (1) ease of use and accessibility, (2) content comprehensibility, (3) visual appeal, and (4) usefulness of the technology. In addition, students were invited to provide open-ended comments regarding their learning experience. A summary of the students' comments is presented in Table 7.

Table 7. Summary of Student Comments in the Small-Group Stage

Student Initials	Low SES (1,2)
AR	"I understand scale better because I can directly see the distance on the map and the actual distance in Scratch."
FN	"The buttons in the application are easy to use after reading the instructions, and the problems are not just calculations."
LM	"Learning is more enjoyable because I can move the map around. It feels like using a real map."
RS	"I was confused at first, but after the first example was explained, the following activities became easier to follow."
NA	"The colors and design of the worksheet are attractive, not boring like regular paper worksheets."
HF	"I feel that I understand how scale works better, not just memorizing formulas."

The results of the practicality questionnaire were then analyzed and summarized in Table 8.

Table 8. Practicality Results of the Scratch-Assisted Digital Worksheet

Aspect	Percentage	Category
Ease of Use and Accessibility	82.50%	Practical
Content Comprehensibility	84.00%	Practical
Visual Appeal	83.80%	Practical
Usefulness of Technology in the Worksheet	82.20%	Practical
Average	83.12%	Practical

Based on Table 8, the Scratch-assisted Digital Worksheet achieved an average practicality score of 83.12%, categorized as practical. This indicates that the developed product was considered easy to access and use, the content was understandable, the visual design was appealing, and the integration of Scratch provided meaningful support for learning the concept of scale. The students' comments further reinforce these quantitative findings, as they reported that the worksheet helped them more easily connect the concept of scale with real-life experiences through the use of digital maps.

Assessment Phase

The assessment phase was conducted to determine whether Prototype III of the Scratch-assisted Digital Worksheet met the validity and practicality criteria established for this study. The evaluation at this stage focused on two main components: (1) interpreting the expert validation results (content, construct, language, ICT), which yielded an average score of 92.47% (categorized as very valid); and (2) interpreting the student practicality results from the small-group test, which produced an average score of 83.12% (categorized as practical).

Overall, the findings indicate that the product has achieved the required standards of feasibility for use in mathematics instruction on the topic of scale. Specifically:

1. Content aspect: The results show that the worksheet aligns with the curriculum, provides a sequence of activities progressing from concrete–model–symbolic representations, and integrates digital-map contexts that are closely connected to the learning objectives.
2. Construct aspect: The structure of the worksheet-from the introductory activities to the main tasks-supports the process of deep learning, particularly through exploration-based activities and opportunities for reflection.

3. Language aspect: This aspect received a very valid rating, indicating that the instructions were clear, communicative, and easily understood by students.
4. ICT aspect: The high rating in this category reflects the effectiveness of Scratch integration in supporting the visualization of scale concepts, especially through the zoom, drag-map, and distance-measurement features.

In addition, the practicality results show that students perceived the worksheet as:

1. Easy to use (ease & accessibility > 82%),
2. Clear (content comprehensibility > 83%),
3. Visually appealing (visual attractiveness > 83%), and
4. Supported by scratch in a meaningful way (technology usefulness > 82%).

Taken together, these findings demonstrate that Prototype III is feasible and ready for implementation.

Discussion

Validity of the Scratch-Assisted Digital Worksheet

The validity score of 92.47% (categorized as very valid) indicates that the worksheet meets the required quality standards in terms of content, construct, language, and ICT. This result is consistent with several previous studies on the development of digital media in mathematics education. (1) Ardiansah & Zulfiani (2023) reported an average validity score of 90.06% in the development of a creativity-based e-LKPD, supporting the conclusion that digital media can achieve a "very valid" category when designed according to sound pedagogical principles. (2) Pratiwi et al. (2023) also found validity scores above 89% in Expression Learning–based e-worksheets, reinforcing the notion that media feasibility is strongly influenced by clear and consistent activity structures. (3) The findings are further aligned with Amir et al. (2025), who concluded that valid digital learning materials can enhance students' conceptual understanding and learning readiness.

The high validity scores for the content and construct aspects in this study indicate that the integration of digital-map contexts and the PMRI approach (concrete - model - symbolic) was successfully implemented. This integration strengthens students' understanding of scale through exploratory experiences rather than formula memorization.

Practicality of the Scratch-Assisted Digital Worksheet

The practicality score of 83.12% (categorized as practical) suggests that the worksheet is easy to use and provides a positive learning experience. These findings are supported by earlier research: (1) Asfrianti & Gusmania (2024) found that a digital worksheet–based mathematics e-module achieved a practicality score of 86% and significantly facilitated students' independent learning. (2) Azzahro & Handayani (2025), in developing LiveWorksheets-based e-LKPDs, also reported a "practical" category, particularly for visual appeal and ease of navigation. (3) Wahyuni et al. (2023) stated that integrating GeoGebra into digital worksheets increases practicality because dynamic visualizations make conceptual exploration easier.

Overall, the high practicality rating demonstrates that Scratch effectively serves as an interactive tool that helps students understand scale through digital-map visualization rather than static text.

CONCLUSION

Based on the results of the study, it can be concluded that the Scratch-assisted Digital Worksheet on the topic of scale within a digital-map context has met the validity and practicality criteria as a mathematics learning medium. Expert validation showed a validity level of 92.47%, categorized as very valid, indicating that the content, structure, language, and technological aspects align with the required standards of learning material feasibility. Meanwhile, the practicality test conducted in the small-group stage yielded a percentage of 83.12%, categorized as practical, meaning that the worksheet is easy to use, its instructions are clear, its visual design is appealing, and the Scratch technology provides tangible benefits in helping students understand the concept of scale. The integration of digital-map contexts and Scratch simulations effectively supported the implementation of deep learning, particularly in mindful, meaningful, and joyful learning components. Students were able to explore the relationship between map distance and actual distance in a more concrete, dynamic, and interactive manner, enabling them to develop not only procedural understanding but also conceptual and applied comprehension of scale. In addition, the learning experience offered by the worksheet helped reduce students' tendency to merely memorize formulas and instead encouraged them to build understanding through exploration, reflection, and contextual interpretation.Therefore, the Scratch-assisted Digital Worksheet developed in this study is deemed feasible for use in mathematics instruction on the topic of scale and has the potential to enhance learning quality by strengthening deeper and more meaningful learning experiences for students.

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