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Development of Digital Interactive Worksheets Based on a Differentiated Instruction Model in Science Education to Enhance Scientific Literacy in Physics Among Junior High School Students

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Abstract: The integration of technology in education is essential for enhancing learning, particularly in junior high school Science. Challenges such as low conceptual understanding and limited scientific literacy remain prevalent. This study developed a differentiation-based Digital Interactive Worksheet (DIW) to improve students' scientific literacy in motion concepts. Using the ADDIE model within a Research and Development (R&D) framework, the study involved 30 eighth-grade students at SMP Negeri 5 Padangsidimpuan. Data were collected through expert validation sheets, practicality questionnaires, and scientific literacy tests. Results indicated that the DIW was highly valid (81.2%), practical (84.6%), and effective in enhancing students' scientific literacy. Small-scale trials produced an N-Gain of 55.8% (moderate), while large-scale trials showed an N-Gain of 49.9% (moderate), suggesting consistent effectiveness, though slightly lower in larger classes likely due to management challenges. The 5.9% difference highlights the importance of classroom strategies for larger groups. DIW's success is attributed to interactivity, personalized learning, real-time feedback, and active student engagement. This study contributes a tested digital learning tool for Science education and demonstrates the effective integration of differentiation and technology. The findings support SDG 4 (Quality Education) through inclusive and adaptive learning. Future research should address scalability and broader classroom implementation.

Keywords: Digital interactive worksheet; Differentiation model; Science literacy; Motion concept

Introduction

The integration of technology in educational settings has emerged as an urgent necessity for improving learning effectiveness, particularly in Natural Science subjects at the junior high school level. However, significant challenges persist that contribute to students' inadequate conceptual understanding and limited science literacy. The Programme for International Student Assessment (PISA) 2022 report reveals that Indonesian students' science literacy scores reached only 383 points, substantially below the Organisation for Economic Co-operation and Development (OECD) average of 485 points (OECD, 2023), underscoring the critical need for innovative pedagogical approaches. Similar findings emerged from the Computer-Based

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National Assessment (ANBK) 2023, wherein more than 60% of Indonesian junior high school students remained categorized as "requiring intervention" in science literacy (Kemdikbud, 2023).

This deficiency in science literacy stems primarily from the absence of interactive and adaptive learning media. Contemporary research emphasizes that science literacy encompasses not merely conceptual understanding but also the capacity to engage meaningfully with science-related issues as reflective citizens (Busch et al., 2024; Sarini et al., 2024). Uniform instructional methods that fail to accommodate individual learning styles and comprehension levels impede deep understanding of abstract physics concepts (Yli-Panula et al., 2018).

Consequently, innovative learning strategies that are more flexible and personalized are essential, enabling each Concurrent with technological advancement, educational trends demonstrate increased utilization of digital learning media as instruments for enhancing student comprehension (Momani et al., 2023). Utilizing technological and scientific progress has become a crucial element in enhancing the learning process (Wijaya et al., 2025).The integration of artificial intelligence and advanced educational technologies has created unprecedented opportunities for personalized learning experiences (Kim et al., 2022). Interactive digital learning media can increase student engagement by up to 30% compared with conventional methodologies.

One promising innovation in science education is the interactive digital worksheet, which constitutes a digital learning tool incorporating interactive features such as animations, simulations, and adaptive exercises. Digital Interactive Worksheets (DIW) enable students to participate actively in the learning process, thereby enhancing their understanding of scientific concepts (Cao et al., 2021; Muttaqiin et al., 2024). Previous research has predominantly focused on the effectiveness of digital media in learning without integrating differentiation models (Langelaan et al., 2024) despite differentiation being crucial for addressing diverse learning needs. Research on interactive digital worksheets remains limited to general applications without adaptation to differentiation principles (Bi et al., 2023; Pozas et al., 2021).

Theoretically, this research is supported by several contemporary educational frameworks. Constructivist learning theory emphasizes active knowledge construction through interaction, and recent studies have shown that applying constructivist principles with digital tools can improve engagement and conceptual understanding in science learning (Charania et al., 2021; Sarwar et al., 2024). Cognitive Load Theory highlights the importance of reducing extraneous load and enhancing meaningful processing, with adaptive multimedia proven effective in optimizing student learning (Paas et al., 2020; Sweller et al., 2019). Differentiated Instruction provides a strong basis for accommodating students' diverse readiness, interests, and learning profiles, with recent research confirming its positive impact on academic achievement and engagement (Bi et al., 2024; Kurniawati et al., 2018; Smale-Jacobse et al., 2019). Similarly, Universal Design for Learning (UDL) offers principles of accessibility and inclusivity, and recent findings demonstrate its effectiveness in supporting diverse learners and improving STEM education outcomes (Almeqdad et al., 2023; Stephens et al., 2025). Finally, the Technology Acceptance Model (TAM) underscores the role of perceived usefulness and ease of use in technology adoption, which has been reaffirmed in studies of digital and AI-based learning tools (Ghimire et al., 2024). Collectively, these frameworks justify the development of interactive digital worksheets based on differentiation as an innovative and feasible approach to enhancing junior high school students' science literacy.

Technology-based educational products, specifically DIWs designed using a Differentiated Instruction Model, are both valid and effective in enhancing students' analytical thinking. By integrating differentiated learning strategies in science education, particularly in physics, these worksheets aim to improve junior high school students' scientific literacy, enabling them to better understand, analyze, and apply physics concepts in various contexts (Nasution et al., 2025).

Differentiation-based learning has demonstrated effectiveness in improving educational outcomes by accommodating differences in abilities, interests, and learning styles. Kasmawati et al. (2024) emphasize that implementing differentiation-based learning in integrated science materials can enhance teacher competency, facilitate student ability evaluation, and provide meaningful learning innovations by connecting scientific concepts with local cultural contexts. This approach becomes increasingly relevant when applied to digital learning media, providing adaptive learning experiences tailored to individual student characteristics (Nasution et al., 2024).

Beyond theoretical grounding, there are strong rationales for conducting this research. First, Indonesia's underperformance in both PISA and ANBK results demonstrates the urgency of improving science literacy. Second, existing instructional practices are limited in addressing student diversity, necessitating adaptive solutions. Third, this study aligns with global educational trends and national policy directions that prioritize digitalization and personalization in learning. Fourth, the integration of differentiation principles into DIWs represents a novel contribution, filling the gap left by prior research. Finally, this development not only

supports student achievement but also strengthens teacher competencies in implementing adaptive pedagogy, ensuring sustainability and broader educational impact.

The concept of differentiated learning has garnered considerable attention in educational research over the past two decades, with studies demonstrating its positive impact on student achievement and engagement (Smale-Jacobse et al., 2019; Sun et al., 2021). Effective differentiation involves systematic adaptation of instructional methods to accommodate diverse learner needs (Cairns et al., 2019) and, when implemented effectively, can significantly enhance engagement across various educational levels (Moallemi, 2024). Furthermore, differentiated learning serves as a viable framework for addressing diverse learner requirements, particularly when combined with universal design principles (Colbert et al., 2023; Hidayat et al., 2025).

The differentiation model exerts positive influences on students' science achievement and dispositions across various educational contexts through effective pedagogical approaches that provide varied methods for delivering information to students in diverse classroom environments (Mulbar et al., 2018; Safitri et al., 2023). Supporting science literacy requires comprehensive strategies that address both conceptual understanding and scientific thinking skills (Sjöström et al., 2018). This research develops interactive digital worksheets based on differentiation models, aimed at enhancing students' science literacy by integrating interactive features with adaptable learning pathways. Unlike conventional digital media, these interactive digital worksheets accommodate students' learning styles and pacing through visual, auditory, interactive simulations, and adaptive exercises, with effectiveness evaluated across cognitive, affective, and scientific thinking dimensions.

Based on this background, the research questions are formulated as follows: (1) How can Digital Interactive Worksheets based on differentiation models be developed to meet the requirements of science learning at SMP Negeri 5 Padangsidimpuan? (2) What is the feasibility of Digital Interactive Worksheets based on differentiation models for enhancing students' science literacy? (3) How does the effectiveness of Digital Interactive Worksheets based on differentiation models compare with conventional learning methods?

Method

This research employed a Research and Development (R&D) methodology to develop Digital Interactive Worksheets based on differentiation models, with the objective of enhancing junior high school students' physics science literacy. This approach facilitates the development of interactive learning media based on student needs while ensuring systematic testing to verify effectiveness. To support the systematization of DIW development, this research adopted the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), which provides a clear framework for designing, developing, and evaluating technology-based learning products (Islam et al., 2023; Li et al., 2023; Sial et al., 2024).

The development process of Digital Interactive Worksheets based on differentiation models commenced with the analysis phase, which aimed to identify problems and requirements of students and teachers related to science learning, particularly in understanding scientific concepts, especially motion material for grade VIII students. Analysis activities encompassed classroom observations to identify learning challenges, particularly regarding motion material; interviews with teachers and students to explore conceptual understanding barriers; literature studies referencing Indonesian students' low science literacy based on PISA data; and needs analysis for more effective interactive learning media.

This research was conducted in 2025 at SMP Negeri 5 Padangsidimpuan. The study population consisted of 120 eighth-grade students. From this population, the research sample was selected in stages through small- and large-scale trials. The small classroom testing involved 10 eighth-grade students as initial subjects to examine the feasibility and necessary improvements of the product. Subsequently, the large classroom testing was carried out with 20 eighth-grade students as the main subjects to evaluate the practicality and effectiveness of the Differentiation-Based Digital Interactive Worksheet in enhancing students' science literacy. This sampling procedure allowed the researcher to obtain a comprehensive overview of the product's validity, practicality, and effectiveness before broader implementation.

Subsequently, the design phase focused on creating Digital Interactive Worksheets that meets the demands of interactive science learning based on differentiation principles. This design process included determining primary features such as animations, simulations, adaptive exercises, and real-time feedback; organizing content according to students' comprehension levels; designing attractive and user-friendly interfaces; and developing Digital Interactive Worksheets implementation scenarios for learning contexts.

The development stage followed, wherein was actualized in digital format using interactive software. Visual, auditory, simulation, and adaptive exercise features were integrated into the product, followed by validation testing conducted by material and media

experts to ensure content accuracy and design effectiveness, accompanied by initial revisions based on validator feedback.

During the implementation phase, Digital Interactive Worksheets was applied in classroom science learning, followed by application to grade VIII students, with effectiveness data collection conducted through science literacy tests, observations, and student satisfaction questionnaires.

Finally, the evaluation phase was conducted to assess Digital Interactive Worksheets effectiveness and refine the product. Evaluation encompassed analysis of student test results to measure science literacy improvement, questionnaire and interview analysis to understand teacher and student perceptions, and final revisions based on field findings to enhance Digital Interactive Worksheets quality. The development model is illustrated in the following diagram

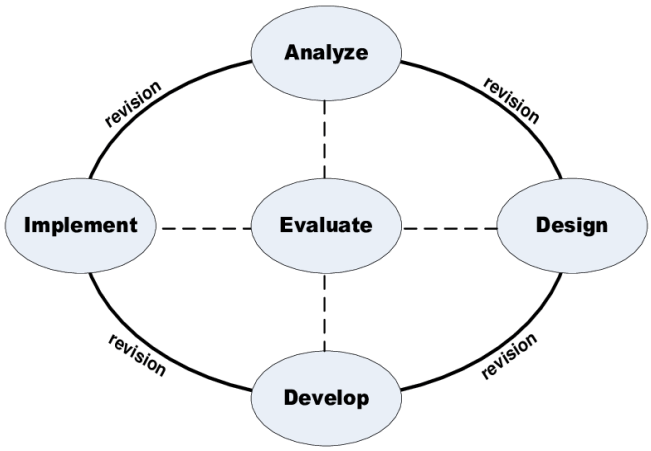

Figure 1. Research flow diagram

This research was conducted at SMP Negeri 5 Padangsidimpuan, involving thirty grade VIII students as primary subjects. Data collection instruments included expert validation sheets for material experts, media experts, and language experts; practicality questionnaires for teachers and students; and science literacy test instruments for pre-test and post-test assessments.

Data analysis in this research was conducted to determine the validity, practicality, and effectiveness levels of the developed product. The analysis process was performed quantitatively based on expert validation results, teacher and student responses, and student learning outcomes.

The first stage involved validity testing aimed at measuring the feasibility of learning media based on assessments by media experts and material experts. The assessment criteria were established as follows:

Table 1. Validity Category Criteria

Percentage (%)	Category
81-100%	Very Valid
61-80%	Valid
41-60%	Moderately Valid
< 40%	Invalid

The second stage comprised practicality testing that assessed the ease of use and classroom application of learning media based on teacher and student questionnaires. The practicality criteria categories were defined as:

Table 2. Practicality Category Criteria

Percentage (%)	Category
81-100%	Very Practical
61-80%	Practical
41-60%	Moderately Practical
< 40%	Impractical

The third stage involved effectiveness testing that measured the extent to which learning media could improve student learning outcomes through comparison of pre-test and post-test scores and N-Gain Score calculation using the following formula:

$$G = \frac{Posttest\ Score - Pretest\ Score}{\text{Maximum Score} - \text{Pretest}}\ x\ 100\ \% \quad (1)$$

The criteria categories were established as:

Table 3. N-Gain Interpretation Criteria

N-Gain Score	Effectiveness Category
> 0.70	High
0.30 – 0.70	Moderate
< 0.30	Low

Result and Discussion

Based on research conducted at SMP Negeri 5 Padangsidimpuan, researchers successfully developed Digital Interactive Worksheets based on differentiation models to enhance students' science literacy in motion concepts for grade VIII students. This research utilized Research and Development (R&D) methodology with the ADDIE model, encompassing analysis, design, development, implementation, and evaluation phases. The research findings demonstrate that the developed Digital Interactive Worksheets meets the criteria for validity, practicality, and effectiveness in science learning applications.

Digital Interactive Worksheets development process was conducted systematically by incorporating analysis of teacher and student needs, design based on differentiated learning principles, validation by material and media experts, and progressive testing from small

classes to large groups. Each development stage provided valuable input for product improvement, resulting in learning media that addresses the requirements of science education at the junior high school level.

All Digital Interactive Worksheets components were designed according to differentiated learning principles that consider diversity in students' abilities, interests, and learning styles, enabling each student to learn according to their individual characteristics. Qalfin et al. (2024) reported that differentiated digital worksheets based on socio-scientific issues significantly improved students' science literacy with an N-gain of 0.582, outperforming control groups. Similarly, Yuberti et al. (2019) found that STEM-based interactive e-books developed through the ADDIE model were feasible and effective in enhancing science literacy, with an average N-gain of 0.56. Furthermore, Mayasari et al. (2023) demonstrated that interactive e-worksheets on addictive substances and food additives improved students' science process skills with a high N-gain of 0.72. In line with this, Sulistiani et al. (2024) showed that differentiated learning supported by STEM-based student worksheets on alternative energy materials enhanced both science process skills and creative problem-solving abilities.

Collectively, these findings provide strong empirical evidence that the development of differentiation-based Digital Interactive Worksheets, as implemented in this study, is both relevant and effective in addressing the persistent challenges of low science literacy among Indonesian junior high school students.The following figures present the interactive multimedia learning media based on auto-play functionality developed by the researchers.

Figure 2. Front view interface

Figure 3. Digital interactive worksheet content interface

Following the design and development of the product, the subsequent step involved testing product feasibility through the involvement of material experts and media experts. Testing was conducted using validation questionnaire instruments with assessment scales and the developed product. This validation testing proved essential for determining the feasibility and appropriateness of the media designed by researchers (Armiyati et al., 2025). Assessment results from validators, in the form of suggestions and feedback, were utilized by researchers to improve the developed media.

Figure 4. Learning handout

Validation of Digital Interactive Worksheets based on differentiation models was conducted by material

experts and media experts. The validation aimed to assess content feasibility, curriculum compatibility, and learning media design quality.

Table 4. Expert Validation Results

Aspect	Score (%)	Category
Material Expert	80.5	Very Valid
Media Expert	82.0	Very Valid
Content Expert	81.2	Very Valid

Based on expert validation results, Digital Interactive Worksheets based on differentiation models achieved an overall validity percentage of 81.2% with "Very Valid" classification. This assessment encompasses three primary aspects: material, media, and content. Regarding the material aspect, Digital Interactive Worksheets obtained an average score of 80.5% with very valid classification, demonstrating content compatibility with the junior high school science curriculum, integrated implementation of differentiation models, and clarity in motion concept presentation. The media aspect received the highest score of 82.0% with very valid classification, reflecting excellence in attractive interface design, superior interactivity quality, ease of navigation, and appropriate multimedia utilization. Meanwhile, the content aspect achieved a score of 81.2% with very valid classification, confirming accuracy in Indonesian language usage, clarity of usage instructions, and language appropriateness for junior high school students' comprehension levels. These results align with findings from Costadena et al. (2022) who assert that high-quality adaptive Digital Interactive Worksheets can enhance science learning. Given the high validity levels across all aspects, the developed Digital Interactive Worksheets is deemed suitable for implementation in junior high school science learning based on content, design, and linguistic standards.

Following expert validation, Digital Interactive Worksheets underwent testing in a small classroom setting consisting of eight grade VIII students at SMP Negeri 5 Padangsidimpuan. Small-scale testing aimed to identify technical issues and obtain initial user feedback before large-scale implementation.

Based on testing results, the practicality level of Digital Interactive Worksheets demonstrated significant improvement from small classroom testing to large classroom testing phases. In small classroom testing involving eight students, Digital Interactive Worksheets practicality percentage reached 80.0% with "Practical" classification. Although the system functioned adequately, several aspects requiring improvement were identified to enhance user experience, including: (1) enlarging font size in certain sections to improve readability, (2) clarifying inter-page navigation through the addition of "Next" and "Previous" buttons, and (3) adjusting video simulation duration to be more concise and focused on core learning objectives. This stage aligns with user-centered design principles in the ADDIE development model, which emphasizes the importance of direct user involvement to identify product weaknesses before large-scale implementation.

Following revisions, large classroom testing was implemented with thirty grade VIII students and three science teachers at SMP Negeri 5 Padangsidimpuan. Results demonstrated an increase in practicality percentage to 84.6% with "Very Practical" classification. All assessment aspects achieved high scores: ease of use (86.6%), learning compatibility (83.8%), media attractiveness (85.0%), time efficiency (83.0%), and differentiation implementation (84.4%). Teachers provided positive assessments regarding the ease of integrating Digital Interactive Worksheets into the learning process and its support for implementing differentiated learning approaches. Students also responded positively, particularly regarding ease of use and visual appeal of the media.

The improvement from 80.0% in the small classroom stage to 84.6% in the large classroom stage demonstrates that revisions based on user feedback significantly impact Digital Interactive Worksheets quality and usability. These results reinforce that iterative approaches in digital learning media development are highly effective for ensuring products genuinely meet practical field requirements. The following graph illustrates Digital Interactive Worksheets practicality testing results:

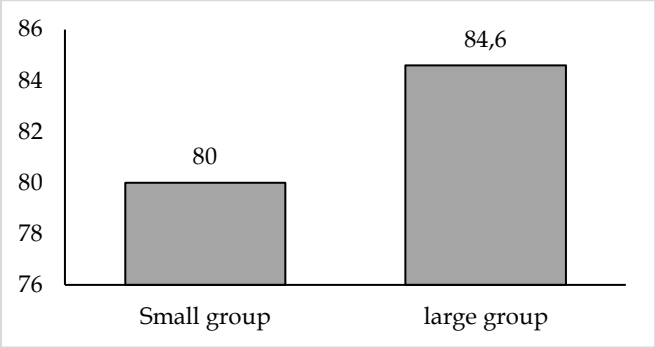

Figure 5. Practicality test comparison

The significant improvement from small classroom to large classroom testing (80.0% to 84.6%) demonstrates the effectiveness of iterative processes in the ADDIE development model that emphasizes continuous improvement (Islam et al., 2022). The very high practicality level (84.6%) indicates that Digital Interactive Worksheets can be easily implemented in daily learning activities. Teachers reported that user-friendly interfaces facilitate operation, while interactive

features such as simulations and animations enhance student engagement. This finding is consistent with research by Estaiteyeh et al. (2023) who found that interactive digital learning media increases student motivation and participation. These results indicate that the developed Student Worksheets fall under the very practical category for use in classroom learning (Cyndirela et al., 2025). Positive responses from both teachers and students indicate that Digital Interactive Worksheets successfully addresses practical needs in implementing differentiated learning approaches.

Effectiveness testing was conducted to determine the effectiveness of using Digital Interactive Worksheets based on differentiation models in enhancing grade VIII students' science literacy. The research was conducted through two testing phases: small classroom testing and large group testing. Small classroom testing was performed to assess the effectiveness of Digital Interactive Worksheets based on differentiation models in motion material instruction. Small classroom testing involved eight students from grade VIII at SMP Negeri 5 Padangsidimpuan. The testing activity sequence commenced with opening the learning process, followed by students taking pre-tests to determine initial knowledge levels before receiving motion material using Digital Interactive Worksheets , then researchers provided motion material using Digital Interactive Worksheets based on differentiation models, and concluded with students taking post-tests to determine comprehension levels after receiving material using Digital Interactive Worksheets . The pre-test and post-test results for small classrooms are presented in the figure 6.

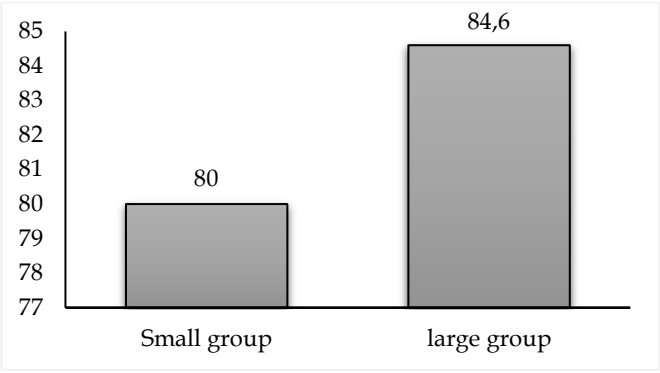

Figure 6. Average pre-test and post-test results for small groups

Based on small classroom testing results, the pre-test average score was 57.5, while post-test results yielded an average score of 81.2. The data reveals that average pre-test and post-test scores increased by 23.7 points. Subsequently, normality testing was conducted to examine pre-test learning outcomes obtained before using Digital Interactive Worksheets and post-test outcomes after using Digital Interactive Worksheets. Normality testing aimed to determine whether data followed normal distribution patterns.

Table 5. Small Classroom Normality Test Results

Statistics	Significance	Distribution
Pre-test	0.746	Normal
Post-test	0.824	Normal

Small classroom normality test analysis results, with significance values of 0.746 and 0.824 (greater than 0.05), indicate that both pre-test and post-test data follow normal distributions. Subsequently, t-testing or paired sample t-testing was conducted to determine differences in student learning outcomes before and after using Digital Interactive Worksheets based on differentiation models.

Table 6. Small Classroom t-Test Results

	Average	Average differences
Pre-test	57.5	23.7
Post-test	81.2	

Based on the above data, the average score difference between pre-test and post-test for small classrooms is 23.7, with t-value = 8.456 and significance level of 0.000 ($p < 0.05$), indicating statistically significant differences between pre-test and post-test results. The subsequent step involved conducting N-gain testing to measure the effectiveness of science literacy improvement after using Digital Interactive Worksheets based on differentiation models.

Table 7. Small Classroom N-Gain Test Results

Average difference	N-gain	Criteria
23.7	0.558	Moderate

Based on the above table, the N-gain value or average improvement from pre-test and post-test results for small classrooms is 0.558 (55.8%), placing it within moderate criteria. These results demonstrate improvement in student learning outcomes achieved through learning using LKID based on differentiation models in grade VIII at SMP Negeri 5 Padangsidimpuan.

The subsequent step conducted by researchers involved large group testing. The large group research target comprised one complete class of thirty grade VIII students at SMP Negeri 5 Padangsidimpuan. Researchers conducted normality testing on pre-test and post-test scores, t-tests, and normalized-gain score tests or N-gain score assessments. The pre-test and post-test results for large groups are illustrated in the figure 7.

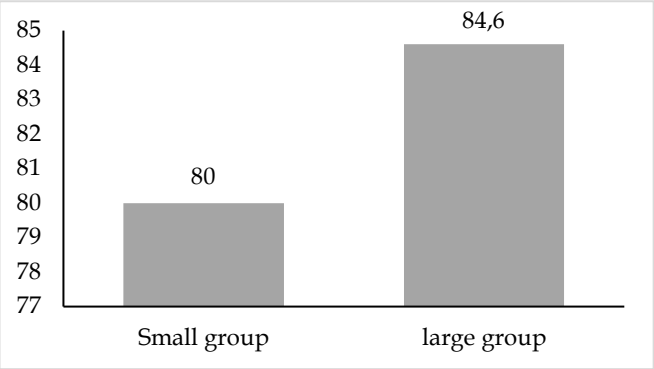

Figure 7. Pretest and posttest results for large groups

Based on large group testing results involving thirty students, the pre-test average score was 58.7, while the post-test average score reached 79.3. The observed improvement was 20.6 points. The following presents normality testing results:

Table 8. Large Group Normality Test Results

Statistics	df	Sig.	Distribution
Pre-test	30	0.342	Normal
Post-test	30	0.678	Normal

Large group normality test analysis results, with significance values of 0.342 and 0.678 (greater than 0.05), confirm that both pre-test and post-test data follow normal distributions. The subsequent step involved conducting t-testing.

Table 9. Large Group t-Test Results

	Average	Average differences
Pre-test	58.7	20.6
Post-test	79.3	

Based on the above data, the average score difference between pre-test and post-test for large groups is 20.6, with t-value = 15.432 and significance level of 0.000 ($p < 0.05$), demonstrating statistically significant differences between pre-test and post-test results. The subsequent step involved gain testing.

Table 10. Large Group N-Gain Test Results

Average difference	N-gain	Criteria
20.6	0.499	Moderate

In testing Digital Interactive Worksheets effectiveness, N-gain testing is essential. Large group N-gain testing was conducted to determine learning outcome improvement after using Digital Interactive Worksheets based on differentiation models. Based on the above data, the average improvement of pre-test and post-test scores in large groups is 0.499 (49.9%) with moderate classification. These results demonstrate average score improvement in pre-test and post-test assessments conducted during learning using LKID based on differentiation models in grade VIII at SMP Negeri 5 Padangsidimpuan.

Analysis results demonstrate that Digital Interactive Worksheets (LKID) based on differentiation models are proven effective in enhancing junior high school students' science literacy. Normality testing confirms that data follows normal distribution patterns ($p > 0.05$), justifying the use of parametric tests. Small classroom testing with eight students produced an N-Gain of 55.8% (moderate category) with an average improvement of 23.7 points, while large group testing with thirty students achieved an N-Gain of 49.9% (moderate category). The 5.9% effectiveness difference between both groups indicates that although slight decreases occur on larger classroom scales, LKID remains effective across various learning contexts. This success is attributed to interactivity that facilitates visualization of abstract concepts, learning personalization according to students' learning styles and pacing, provision of real-time feedback, and active student engagement. These findings are consistent with research Kelp et al. (2023) and Wang et al. (2022) confirming the effectiveness of inquiry-based approaches and interactive digital media. Practically, teachers can utilize LKID as primary media in science learning with support from classroom management strategies, technology training, and cooperative methods to maximize learning outcomes, while theoretically, this research strengthens the concept of integrating differentiation and digital technology as innovative solutions for science learning in the digital era.

Conclusion

This study concludes that Digital Interactive Worksheets (DIWs) based on differentiation models were successfully developed and proven valid, practical, and effective in enhancing junior high school students' science literacy. The validity results, with an average expert assessment score of 41.9 (82.9%, very valid), confirm that the DIWs meet both content and design feasibility standards for science learning. Practicality testing, conducted progressively from small to large groups, showed improvement from 80.0% to 84.6% (very practical), highlighting the effectiveness of iterative ADDIE-based development in producing user-friendly products for teachers and students. In terms of effectiveness, the DIWs consistently improved students' science literacy with N-gain scores of 55.8% in small groups and 49.9% in larger groups (both in the moderate category), with a 5.9% difference indicating that while DIWs can be applied effectively across varied learning

contexts, larger groups require stronger management strategies to optimize outcomes. Beyond practical benefits, this research contributes theoretically by integrating differentiated instruction with digital technology, reinforcing its role in inclusive and adaptive learning. Ultimately, the findings align with the pursuit of Sustainable Development Goal 4 (Quality Education), offering a replicable model for developing future digital learning innovations in science education.

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Author Contributions

The research team assumed responsibility for research conceptualization, science learning needs analysis, DIW conceptual framework design based on differentiation principles, content development supervision, trial implementation, and effectiveness evaluation. Additional responsibilities included needs analysis through teacher and student interviews, DIW-based learning strategy design, material development according to various learning styles, implementation observation, statistical analysis of effectiveness test results, technology analysis, UI/UX design, interactive feature development including animations, simulations, and adaptive exercises, system testing, and technical improvements based on user feedback.

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Conflicts of Interest

The authors declare no conflicts of interest in this research.

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