



DEVELOPMENT OF DISCOVERY LEARNING-BASED MATHEMATICS LEARNING MEDIA ACCOMPANIED BY CROSSWORD PUZZLES OF INTEGER MATERIAL

Lidia Marsela Putri¹, Nego Linuhung^{2*}, Ira Vahlia³

^{1,2,3}Universitas Muhammadiyah Metro, Kota Metro, Indonesia

*Corresponding Author: negolinuhung@gmail.com

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Abstract. This study aims to develop android-based mathematics learning media using a discovery learning approach and crossword puzzle games on the topic of integers for SMP Negeri 4 Metro. The development model used is ADDIE, which includes the stages of analysis, design, development, implementation, and evaluation. The analysis stage was conducted through interviews with educators and student questionnaires to identify media needs. In the design stage, interactive media combining discovery learning and games was developed. The development stage included validation by subject matter and media experts, resulting in a very good score of 86.5%. Implementation showed that the media was practical to use, with a 93% success rate, and evaluation was conducted continuously to improve the product. The results of the study indicate that the learning media are highly valid and practical for use in teaching integers. It implies that this media can be an innovative solution to enhance student engagement and the effectiveness of mathematics learning, and it has the potential to be further developed for other topics and educational levels to create more interactive and flexible learning.

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Correspondence address:

Jl. Ki Hajar Dewantara, Iringmulyo, Kota Metro – Lampung.

negolinuhung@gmail.com

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primagistrauniflor@gmail.com

INTRODUCTION

21st-century education requires the younger generation to possess critical, creative, collaborative, communicative, and competitive thinking skills, summarized in the profile of the golden generation (Rahayu et al., 2023). This requires a learning transformation that actively and meaningfully shapes students' character and competencies (Rini et al., 2021). One of the key skills of this century is critical thinking, which is an important foundation for decision-making, problem-solving, and innovation development (Halim, 2022). The education process itself is an important means of developing high-quality human resources, which continues to advance alongside advances in science and technology (Astuti et al., 2023).

The development of digital technology offers significant opportunities in education, especially in creating more engaging and meaningful learning media. Technology can enrich students' learning experiences and make it easier for teachers to convey material through various media such as projectors, audio-visuals, and educational games (Hidayat et al., 2020). Digital game-based learning, such as crossword puzzles, has been shown to improve students' accuracy, logic, and understanding of concepts (Maftuhah & Rochintaniawati, 2023; Aisyah et al., 2019). One subject that requires an innovative learning approach is mathematics. Mathematics is often considered abstract and difficult by students, so creative and fun learning alternatives are needed (Arif, 2017). In this case, games are an effective way to increase interest and understanding of mathematical concepts.

The mathematics learning process should not only be a transmission of knowledge from teachers to students, but also an interactive process that allows students to build their knowledge through meaningful activities. Teachers are required to be creative in creating a fun learning atmosphere to increase students' motivation to learn (Meliyanti et al., 2018). One approach that meets these demands is discovery learning, which encourages students to actively explore, observe, and draw conclusions from their learning experiences (Edi & Rosnawati, 2021; Surur & Oktavia, 2019). This approach will run optimally if supported by interactive, contextual, and interesting learning media (Hasan et al., 2021; Sutarti & Irawan, 2017; Tarigan & Siagian,

2015).

Mathematics learning still faces challenges, especially in integer materials. Based on interviews with mathematics teachers at SMP Negeri 4 Metro, the use of technology in learning is not optimal. Students generally use smartphones only for entertainment. The pre-survey results showed that 93% of students had personal smartphones with specifications that supported digital learning. As many as 89% have used educational games, but only 19% have used digital crossword puzzles in mathematics learning. This shows that game-based digital learning media have not been utilized to their full potential.

Several previous studies support the effectiveness of the discovery learning approach in improving critical thinking skills and conceptual understanding. [Edi & Rosnawati \(2021\)](#) show that discovery learning-based LKPD is effectively used in mathematics learning, even though technology has not been integrated. [Samosir \(2020\)](#) stated that the use of question cards in the discovery learning model can improve critical thinking skills, but it remains a conventional approach. [Haryanti & Saputro \(2016\)](#) developed a discovery-learning-based mathematics e-module using a flipbook maker, which effectively improved students' understanding of concepts. Meanwhile, [Pamungkas et al. \(2020\)](#) developed a discovery-learning-based mathematics module grounded in Islamic values. However, none of these studies has thoroughly integrated digital games.

Based on this study, this research has novelty in terms of the development of android-based learning media that combines the discovery learning approach with crossword puzzle games. This innovation is expected to increase student engagement and learning motivation, and to create a mathematics learning experience that is more interactive, interesting, and aligned with today's students' characteristics. The purpose of this study is to develop an android-based mathematics learning media with a discovery learning approach and crossword puzzle games on integer materials, as well as to test its validity and practicality in supporting mathematics learning at the junior high school level.

RESEARCH METHODS

This research is a development project that applies the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation ([Branch, 2009](#)). This model was chosen because it is systematic and flexible, enabling the development of learning products tailored to students' needs. An image of the ADDIE model's stages is shown in [Figure 1](#) to clarify the development process for learning media products.

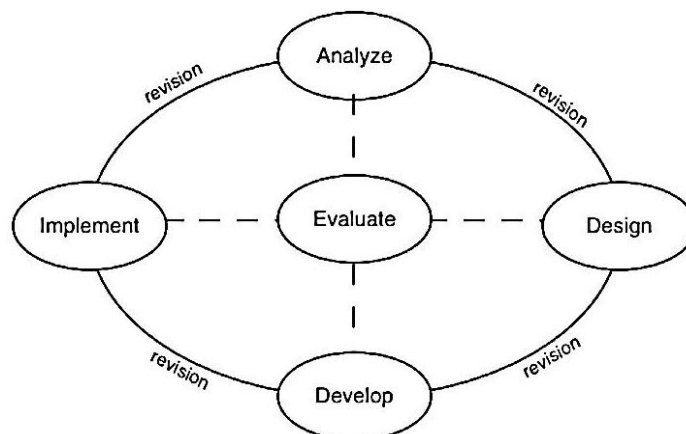


Figure 1. ADDIE Framework According to [Branch \(2009\)](#)

The learning media developed was validated by three experts ([Apsari & Rizki, 2018](#)): two Mathematics Education lecturers at the University of Muhammadiyah Metro and one Mathematics teacher at SMP Negeri 4 Metro. Assessments were carried out on aspects of materials, media, and integration, using a discovery learning approach and elements of crossword puzzle games.

The product trial was conducted with a small group of nine students in class VII-A at

SMP Negeri 4 Metro. Subjects were selected using a stratified random sampling technique (Firmansyah & Dede, 2022) to ensure proportional representation across levels of learning ability. Three learners represent the upper level, three the intermediate level, and three the lower level, based on the learning outcomes provided by the subject teachers.

The research instruments include expert validation sheets and student response questionnaires. Instrument validation is carried out by requesting an expert assessment of the content, construction, and readability of the items. The questionnaire was compiled using a five-point Likert scale to facilitate the interpretation of response data.

Data analysis techniques are further described in Tables 1 and 2, which include methods for assessing validity and practicality. Validity and practicality analysis are carried out using the following formula:

$$\text{Percentage} = \frac{\text{Number of scores given by the validator}}{\text{Maximum number of scores}} \times 100\%$$

The scoring system employs a five-point scale, with each score corresponding to a specific range of percentages and category of validity. The criteria used to interpret the scores are summarized in Table 1.

Table 1. Product Validity Criteria

Weight Value	Rating (%)	Category
5	$80 < N \leq 100$	Highly Valid
4	$60 < N \leq 80$	Valid
3	$40 < N \leq 60$	Less Valid
2	$20 < N \leq 40$	Invalid
1	$0 < N \leq 20$	Highly Invalid

As shown in Table 1, products rated Highly Valid (81–100%) are of excellent quality, while those rated Valid may need minor revisions. Lower categories indicate greater inadequacy and require major improvements before use. Next is the following Formula of Practicality.

$$\text{Percentage} = \frac{\text{Number of scores given by the by students}}{\text{Maximum number of scores}} \times 100\%$$

The interpretation of the practicality score is classified into categories, as shown in Table 2.

Table 2. Product Practicality Criteria

Weight Value	Rating (%)	Category
5	$80 < N \leq 100$	Very Practical
4	$60 < N \leq 80$	Practical
3	$40 < N \leq 60$	Less Practical
2	$20 < N \leq 40$	Impractical
1	$0 < N \leq 20$	Very Impractical

As shown in Table 2, the product can be declared valid if the average percentage obtained exceeds 60%, as shown in Table 1, which contains the product validity criteria. Thus, the product can proceed to the practical test stage. Furthermore, the product is considered practical if the average assessment percentage exceeds 60%, as outlined in Table 2. This shows that the product is worth using.

Analysis of the validity and practicality of the product is an important step in ensuring the quality of the learning media developed. With this approach, it is hoped that the learning media development process can run systematically, based on real needs, and produce products that are effective and suitable for use in mathematics learning in junior high school.

RESULTS AND DISCUSSION

This research produces a discovery-based mathematics learning media, accompanied by a crossword puzzle game, for integer material. Development is carried out through the ADDIE



model, covering the analysis, design, development, and implementation stages. At the analysis stage, it was found that learning at SMP Negeri 4 Metro still relies on packaged books that are less engaging and not yet relevant to students' daily lives. The problem-based learning model applied is not optimal for students with limited initial understanding. Therefore, a more active and engaging approach is needed, such as discovery learning supported by interactive digital media.

The design stage focuses on developing Android-based learning media using software such as PowerPoint, Canvas, Word Wall, and the Web 2 APK Builder. The media is designed with an attractive, interactive appearance and considers aspects of visual comfort and text readability. Design evaluations are conducted to ensure fit with the curriculum and learning objectives. The initial due diligence involves experts assessing the material's quality and the media's appearance.

At the development stage, the media is validated by material and media experts. To ensure the content quality of the developed product, validation was conducted by three material experts (V1, V2, and V3). They assessed four key aspects: Material Suitability, Material Accuracy, Learning Material Support, and Learning Presentation. Each expert provided a percentage rating for each aspect. The average percentage per aspect was then calculated to determine the overall validity level. The results are presented in Table 3.

Table 3. Material Expert Validation Results

Aspects	Percentage			Average Percentage Per Aspect
	V1	V2	V3	
Material Suitability	65%	90%	80%	78%
Material Accuracy	80%	80%	70%	77%
Learning Material Support	70%	100%	100%	90%
Learning Presentation	70%	95%	85%	83%
Average	71%	91%	84%	82%
Information				Highly Valid

Based on the data in Table 3, the average percentage from all experts is 82%, which falls into the Highly Valid category. This indicates that the material meets the required standards for content quality, relevance, and presentation, and that only minor revisions are needed.

To evaluate the technical and design quality of the developed product, a validation process was carried out by three media experts (V1, V2, and V3). The assessment focused on three key aspects: Learning Media Size, Learning Media Content Design, and Media Uses. Each expert provided a percentage score for every aspect, which was then averaged to determine the overall validity. The results are summarized in Table 4.

Table 4. Media Expert Validation Results

Aspects	Percentage			Average Percentage Per Aspect
	V1	V2	V3	
Learning Media Size	85%	90%	90%	88%
Learning Media Content Design	93%	100%	80%	91%
Media Uses	96%	100%	88%	95%
Average	91%	97%	86%	91%
Information				Highly Valid

As shown in Table 4, the average validation result from media experts is 91%, placing it in the Highly Valid category. This indicates that the media components are well-designed, functional, and effectively support learning objectives, requiring little to no revision before implementation.

The implementation stage was carried out through a practical test on nine students of various ability levels. The average practicality obtained reached 93% with the category of very practical. Media is considered attractive, easy to use, and supports independent learning, both online and offline. The crossword puzzle feature has been proven to help learners understand integer material in a fun way, as shown in Table 5.



Table 5. Product Practicality Results

Aspects	Percentage of respondents (%)									Average Percentage Per Aspect
	R1	R2	R3	R4	R5	R6	R7	R8	R9	
Media Quality Aspects	100	100	87	87	80	93	100	93	100	93
Material Quality Aspect	94	94	89	91	86	94	100	91	100	93
Technical Quality Aspects	88	96	88	96	88	100	100	88	88	92
Average	94	97	88	91	85	96	100	91	96	93
Information	Very Practical									

As shown in [Table 5](#), the overall average practicality score is 93%, placing it in the Very Practical category. This indicates that the product is highly usable, well-received by users, and effectively supports the learning process with minimal adjustments needed.

Overall, the learning media developed shows high quality in terms of materials, technicalities, and design, and is considered very practical by users. This media is ready to be used more widely as a support for discovery-based mathematics learning. The findings described in the results section are further analyzed in the discussion section to strengthen the argument and see the compatibility with the foundations and theories of the previous study. At the initial analysis stage, it was revealed that students had difficulty understanding the concept of integers due to a lack of interactive, contextual media. Digital media that support active learning styles is still limited ([Darimi, 2017](#); [Maftuhah & Rochintaniawati, 2023](#)). Research also shows that learning with media that meet students' needs can increase learning effectiveness ([Budiastuti & Fauziati, 2021](#)).

The use of learning media allows students to absorb the material thoroughly and with excitement, as well as to encourage engagement and independence in mathematics learning ([Muhtarom et al., 2016](#)). In the context of understanding mathematical concepts, students who use crossword puzzles show better understanding than those in conventional learning ([Edriati et al., 2017](#)). The media also encourages students to think analytically and reflexively ([Mukarima et al., 2024](#)). At the media design stage, it is designed with a discovery learning approach that encourages students to actively build knowledge. Media is equipped with educational games such as crossword puzzles to increase engagement ([Walidah et al., 2022](#)). This design emphasizes attractive appearance, easy navigation, and high interactivity ([Gulo & Harefa, 2022](#)).

Design is a systematic process and way of thinking to create expected results ([Susanti et al., 2021](#)). [Wibowo \(2023\)](#) emphasized the importance of design principles that create an interactive learning experience and are relevant to students' needs. According to [Putri \(2023\)](#), attractively and contextually designed learning media can significantly improve learning outcomes. Media discovery learning needs to guide students to think critically, explore concepts, and build understanding independently ([Khofiyah et al., 2019](#)). [Evayani \(2020\)](#) also emphasized that media like this create a direct learning experience that places students as active subjects.

Once the design is complete, the media development stage is developed and validated by three experts. The results of the material validation showed an average score of 82%, while the media validation reached 91%. This shows that the media have met feasibility and quality standards ([Handican et al., 2023](#); [Yuliana, 2018](#)). The shortcomings identified include language suitability and the material's organization into several parts ([Ekaningtiass et al., 2023](#)). Media development includes content creation, interface testing, and integration of interactive features ([Utari et al., 2022](#)). According to [Nurfadhillah et al. \(2021\)](#), media is a graphic, photographic, or electronic tool for capturing, processing, and conveying information visually and verbally.

At the implementation stage, a practicality test was conducted with nine students of varying ability levels. The average practicality percentage is 93%, which is very practical. Students stated that this medium helped them understand the material in a fun way, especially through interactive

game features (Ilfa et al., 2023). Attractive visuals, easy navigation, and clear instructions support effective media usage. Interactive digital media has also been shown to increase students' response and engagement with the material (Firmasari et al., 2023).

At the evaluation stage, it shows that this medium is very practical and suitable for widespread use. Some features, such as Wordwall, still require an internet connection. A follow-up evaluation is planned through quantitative effectiveness tests on a larger population. Android-based mathematics learning media that use a discovery learning approach and crossword puzzle games have been shown to encourage active participation, stimulate curiosity, and help students better understand integer concepts (Ilfa et al., 2023; Moto, 2019). The discovery learning approach allows students to discover mathematical concepts on their own through exploration and problem-solving, thereby making them more actively involved in the learning process. The use of games such as crossword puzzles also adds a fun and challenging element that can increase motivation to learn.

The implication is that this media is an innovative alternative to enhance the effectiveness of mathematics learning, especially by fostering an interactive learning environment and encouraging student involvement. The use of flexible Android-based technology also supports learning inside and outside the classroom. Furthermore, this approach can be applied to other materials and developed for different educational levels to expand its impact in supporting active, student-centered learning.

CONCLUSIONS AND SUGGESTIONS

Interactive learning media based on discovery learning, accompanied by crossword puzzle games on integer materials, showed excellent results. The validity rate of the media was 86.5%, while the practicality level was 93%. This media can encourage students' active involvement in exploring material independently and in a fun, interactive, game-based way. In addition, the media has been integrated as an Android application, easily accessible to students. Students should use media in groups to increase interaction and collaboration when solving crossword puzzles, enriching their learning experience.

Educators are also expected to guide the use of this media so that the learning process remains by the principles of discovery learning and helps students understand the material more deeply. Researchers are further advised to develop this media by adding automation features for answer input and difficulty level adjustments to improve the personalization of learning and the effectiveness of the evaluation process.

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