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Development of interactive learning media based on the JIGSAW model to enhance students' understanding of mathematical concepts

Rully Herwindo
Universitas Lampung, INDONESIA

Sri Hastuti Noer
Universitas Lampung, INDONESIA

Sugeng Sutiarso
Universitas Lampung, INDONESIA

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Abstract

Background: Many students experience difficulties in understanding mathematical concepts, which negatively impacts their learning outcomes. Integrating interactive learning media with the Jigsaw learning model offers a potential solution by encouraging collaborative learning and increasing student engagement through dynamic and visual content.
Aims: This study aims to develop and evaluate the effectiveness of interactive learning media integrated with the Jigsaw learning model to improve students' understanding of mathematical concepts in the classroom.
Methods: The research employed a Research and Development (R&D) approach using the ADDIE model. The population consisted of 531 ninth-grade students, with a randomly selected sample of 58 students 25 in the experimental group and 33 in the control group. Data were collected through questionnaires, interviews, expert validation, and concept understanding tests, and analyzed using validation analysis, practicality analysis, normality tests, homogeneity tests, t-tests, and hypothesis testing.
Result: The developed media achieved a material validity score of 84% and a practicality score of 82%. Statistical analysis showed a significant difference between the control and experimental groups ($p = 0.00$), indicating the media's effectiveness in improving students' conceptual understanding.
Conclusion: Integrating interactive media with the Jigsaw model enhances students' comprehension of mathematical concepts by addressing common challenges in collaborative learning. This approach offers practical implications for improving instructional practices and supports the integration of technology in mathematics education.

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INTRODUCTION

Mathematics education holds a vital function in nurturing students' abilities to think logically, systematically, and critically from an early stage. Rather than solely emphasizing procedural fluency or mastery of formulas (Loc et al., 2022), mathematics instruction is increasingly designed to promote deep conceptual understanding and its application to real-life contexts (Anggraini & Fauzan, 2020; Putra et al., 2024). When students internalize mathematical concepts meaningfully, they are better equipped to reflectively address problems, identify recurring patterns, and formulate sound generalizations (Chen et al., 2021; Exintaris et al., 2023; Kartini et al., 2021). In this regard, meaningful mathematics learning becomes a cornerstone for building cognitive resilience and adaptive thinking skills needed for interdisciplinary academic challenges. Consistent with this perspective, numerous international educational frameworks position mathematics as a fundamental tool for preparing students to navigate the complexities of the 21st century an era that increasingly demands advanced reasoning and problem-solving competencies (González-Pérez & Ramírez-Montoya, 2022; Hurskaya et al., 2024).

* **Corresponding author:**
Rully Herwindo, Universitas Lampung, INDONESIA
rullyherwindo7@gmail.com

The significance of conceptual understanding in mathematics education has been widely emphasized. However, implementing a concept-oriented approach in classrooms remains a considerable challenge, particularly in developing countries such as Indonesia (Ridha & Kamil, 2021). The transition from procedural instruction to concept-based learning has not been consistently or fully adopted across all levels of education (Kem, 2022; Morélot et al., 2021). This gap is reflected in the 2022 results of the Programme for International Student Assessment (PISA), which ranked Indonesia 70th out of 81 participating countries (PISSA, 2022). The data suggest that many Indonesian students continue to struggle with applying mathematical concepts to real-life contexts and solving non-routine problems (OECD, 2019). These findings highlight the limitations of current instructional practices in developing robust and transformative mathematical understanding. Consequently, there is an urgent need for learning approaches that are both meaningful and contextually grounded.

A similar issue is also evident in the practical implementation of mathematics instruction in schools. A study conducted among ninth-grade students revealed that only approximately 23% demonstrated a strong conceptual understanding of mathematics. Most students were inclined to rely on mechanical procedures to solve problems but struggled when asked to restate learned concepts, relate them to everyday contexts, or apply them in unfamiliar situations. These findings are supported by teacher interviews, which indicated that mathematics instruction remains predominantly teacher-centered, heavily reliant on textbooks and traditional lectures. The limited use of instructional media that facilitates concept visualization has made it difficult for students to develop comprehensive and applicable understanding (Klerkx et al., 2013; Kuosa et al., 2014; Zhou et al., 2024). This condition underscores the pressing need for instructional innovations that focus not only on final outcomes but also on meaningful learning processes through contextual, participatory approaches that foster active student engagement.

Unfortunately, the instructional strategies employed in most Indonesian schools have yet to fully support the attainment of these learning indicators. Teachers often focus on delivering content and assigning routine exercises, leaving limited opportunities for students to construct their own understanding (Barnett & Hodson, 2001; Stronge, 2018). The predominance of one-way instruction renders student passive recipients of information (Berti et al., 2023; Foushee et al., 2023), thereby restricting opportunities for meaningful discussion, exploration, and reflection on mathematical concepts (Novitasari, 2016). In such environments, students tend to memorize problem-solving procedures without grasping the underlying rationale, making it difficult for them to navigate unfamiliar or non-standard problem situations.

One instructional approach considered effective in enhancing classroom engagement and student understanding is the cooperative learning model known as the Jigsaw technique. This model encourages interdependence among students, as each learner is responsible for mastering a portion of the material and subsequently teaching it to their peers within the group (Saputra et al., 2019; Weidman & Bishop, 2009). Through this process, students not only engage in individual learning but also have the opportunity to teach and engage in discussions activities that naturally reinforce their comprehension of the subject matter (PP et al., 2021; Subiyantari et al., 2019; Weidman & Bishop, 2009). Moreover, the collaborative and democratic learning environment fostered by this approach contributes to increased student confidence and motivation throughout the learning experience.

Nevertheless, the implementation of the Jigsaw model is not without challenges. Issues such as unequal student participation, limited instructional time, and the lack of appropriate learning media often hinder its effectiveness. To address these obstacles, the integration of interactive learning media emerges as a promising solution. Technology-based interactive tools enable students to visualize abstract concepts, engage directly with learning content, and receive real-time feedback. These features enhance students' cognitive and affective engagement during the learning process

(Afify, 2020; Baker, 2010; Chi & Wylie, 2014). When combined with the structured design of the Jigsaw model, interactive media can strengthen both individual and group learning processes, facilitating more rapid conceptual understanding through visualization and self-directed exploration (Damayanti & Rudyatmi, 2020; Putra et al., 2018; Sulfemi & Kamalia, 2020).

Several previous studies have explored the application of interactive learning media and cooperative learning models within educational contexts. Melati et al. (2023) reported that the use of interactive instructional media significantly enhances students' motivation and conceptual understanding in mathematics. Similarly, Rustandi (2021) emphasized the pivotal role of digital media in aiding the visualization of abstract mathematical concepts and increasing student engagement. On the other hand, Akmalia and Cahyani (2021) found that the Jigsaw cooperative learning model fosters students' communication and collaboration skills through peer interaction. Additionally, Stevens and Slavin (1995) highlighted that cooperative learning, in general, is effective in improving academic achievement by promoting structured interdependence among group members.

The majority of existing studies tend to examine the benefits of interactive media and the Jigsaw learning model in isolation. Few investigations have explicitly integrated both components within a unified instructional design, particularly in the context of middle school mathematics education. Moreover, there remains a scarcity of research that directly evaluates the effectiveness of combining interactive media with the Jigsaw model to enhance students' conceptual understanding in mathematics. This study seeks to address that gap by developing and assessing interactive learning media embedded within the Jigsaw instructional framework. Through this integrated approach, the present research aims to contribute to the design of mathematics learning environments that are not only collaborative in nature but also enriched with effective technological support to promote comprehensive conceptual understanding.

METHOD

Research Design:

This study adopts a Research and Development (R&D) approach aimed at designing, developing, and evaluating an educational product that meets the criteria of validity, practicality, and effectiveness (Sugiyono, 2013; Waruwu, 2024). The development model used is the ADDIE model, a structured and iterative framework introduced by Dick and Carey, which includes five phases: Analysis, Design, Development, Implementation, and Evaluation (Molenda, 2003; Muruganantham, 2015). Each phase provides a systematic guideline for producing high-quality instructional media. The ADDIE development model procedure is presented in Figure 1.

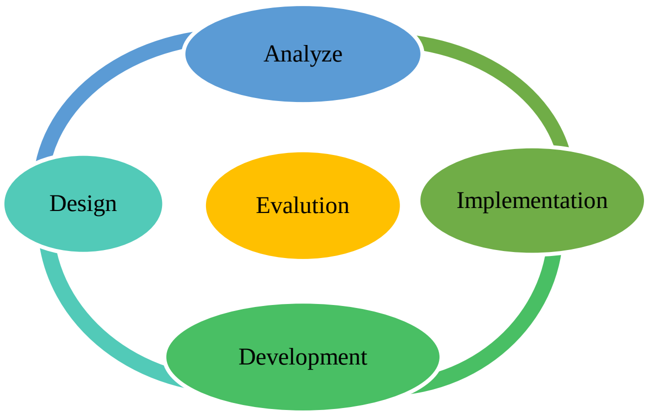

Figure 1. ADDIE Branch Development Research Procedure

The implementation of each phase in the ADDIE model was carried out systematically, beginning with the analysis phase, followed by design and development, and concluding with implementation and evaluation as described below. The analysis phase consisted of two components: pretest analysis and teacher need analysis. The pretest, conducted with class IXD students, revealed generally low levels of conceptual understanding. Specifically, only 71% could restate a concept, 50% could provide examples and non-examples, 32% could explain object properties, 36% could present concepts in mathematical form, 25% could develop necessary and sufficient conditions, 33% could choose and apply specific strategies, and 26% could solve problems using algorithms. Additionally, a curriculum and needs analysis was conducted through interviews with mathematics teachers and review of the *Kurikulum Merdeka*, to ensure alignment with core competencies and identify gaps in the instructional process.

The design and development phase involved creating interactive learning media using various digital tools such as Animaker, Edpuzzle, Wordwall, and Google Sites. The media was structured to support the Jigsaw cooperative learning model and divided into seven main components, including a homepage, competency objectives (CP and ATP), learning content, problem sets, and two interactive educational games. The implementation phase began with expert validation from material and media specialists to ensure the accuracy, clarity, and usability of the product. A small-group trial was then conducted with six students from class IXD selected based on teacher recommendations and one mathematics teacher. The aim was to assess the practicality of the media. Following this, a large-group trial was carried out in class IXA, which served as the experimental group. This trial was designed to evaluate the effectiveness of the developed media in enhancing students' conceptual understanding of mathematics.

The evaluation phase included both formative and summative assessments. Formative evaluation occurred throughout the development process, focusing on improvements and refinements based on expert and user feedback. Summative evaluation, conducted after the implementation stage, assessed the final product's impact on student learning outcomes, specifically the enhancement of conceptual understanding through the integration of interactive learning media within the Jigsaw learning framework.

Participant

The study was conducted at Madrasah Tsanawiyah Negeri (MTsN) South Lampung. The population consisted of 531 students from grade IX, with a sample of 58 students (10.39%) selected using simple random sampling. Of these, 25 students were assigned to the experimental group (class IXA), and 33 students to the control group (class IXB). The division allowed for a comparative analysis of students' conceptual understanding between the two groups.

Instruments

The instruments employed in this study comprised four primary types, each designed to assess validity, practicality, effectiveness, and students' conceptual understanding in mathematics. First, a validation questionnaire was administered to content and media experts to evaluate the appropriateness of content, visual design, and alignment of the media with instructional objectives. Second, a practicality questionnaire was distributed to students and one mathematics teacher to assess the ease and comfort of media use. The results from this instrument provided insight into how effectively the media could be implemented in classroom settings. Third, an effectiveness questionnaire was used to capture students' perceptions of the media's usefulness in enhancing their conceptual understanding of mathematics. Fourth, a conceptual understanding test was developed based on indicators adapted from Purwanti et al. (2016) and Rosmawati & Sritresna (2021). These indicators included the ability to restate concepts, provide examples and non-examples, relate various concepts, apply concepts to problem-solving, and represent concepts in multiple forms. This test was administered both before and after the intervention to quantitatively measure improvements in students' conceptual understanding.

Data Collection

Data were collected through multiple sources: (a) test results of students' mathematical conceptual understanding, (b) validation questionnaires from experts, (c) practicality and effectiveness questionnaires from students and teacher, and (d) interviews with the teacher and students. The diversity of data sources ensured triangulation and strengthened the study's credibility.

Data Analysis

Data analysis began with descriptive statistics of student test scores to identify trends in conceptual understanding. Inferential statistical tests followed, including normality tests, homogeneity tests, and hypothesis testing (independent t-test) to examine whether the use of Jigsaw-based interactive learning media significantly improved students' understanding of mathematical concepts.

RESULTS AND DISCUSSION

The development of interactive media in jigsaw learning that has been developed has met the criteria of valid and practical, by producing an average of validity from material experts reaching 84% and the results of validity from media experts reaching 82%. The results of media practicality from students' validity reached 88.54% and the results of validity from educators reached 91.67%. Based on the results of the posttest hypothesis test t-test on the comprehension of mathematical ideas through the development of interactive media with the jigsaw learning model in students there is a sig <0.05, stating that it is effective in increasing students' ability to understand mathematical concepts.

Table 1. Assessment Score of Questionnaire Instrument from Material Experts

Aspect	Number of Items	Total Score	Validity Score
Material	5	260	87%
Language	1	275	92%
Evaluation	1	225	75%
Average		84%	
Criteria		Very Valid	

Based on Table 1, the material, language and evaluation aspects above, the outcomes of each validator's evaluation have an 87% average score for the material component, 92% for the language aspect and 75% for the evaluation aspect, with an average total achievement of 84%, If the validity range for the material is between 81% and 100%, then the material validity is considered very valid. Validity is an instrument that can be used to measure the relationship between data occurring in the object and data that can be collected by the researcher (Sugiyono, 2013). In addition to material validation, there are media validation results from the assessment of three competent validators in their fields. This media validation instrument consists of design appearance and operational aspects. The results of this assessment contain several inputs or criticisms in the form of suggestions that are used to perfect a product that is being developed. The outcomes of the assessment of the media grid can be seen in table 2 as follows.

Table 2. Media Validation Assessment Results

Aspect	Number of Items	Total Score	Validity Score
Appearance / Design	7	73	87%
Operation	4	37	77%
Average		82%	
Criteria		Very Valid	

Based on the resultsof the media validation assessment from each validator for the assessment of the appearance aspect, the average for the appearance aspect reached 87%, while the assessment of the operational aspect achieved a percentage of 77% with an average of both aspects reaching 82%, If the validity results fall between 63.50 and the validity achievement reaches 82.25, then the validity criteria are classified as high. Based on the results of the two percentage aspects with high valid criteria.

Table 3. Results of Media Practicality Responses from students

Aspect	Number of Items	Total Score	Validity Score
Learning	3	62	86,11%
Material	2	41	85,42%
Media Quality	3	69	95,83%
Language Usage	2	43	89,58%
Media Display	3	64	88,89%
Average		88,54%	

Considering the outcomes of Table 3, the outcomes of the trial of six students of MTsN 2 South Lampung, the learning aspect reached 86.11%, the material and media quality aspect reached 85.42%, the language use aspect reached 95.83% and the media display aspect reached 88.89%, with an average score of 88.54%. From the four aspects, it means that the practicality criteria are very practical. This means that the interactive media can be used by students with low, medium and high abilities. This means that the four aspects contained in the interactive media meet. The following are the results of the responses to the practicality of the media from educators in table 4 as follows:

Table 4. Results of Media Practicality Responses from Educators

Aspect	Number of Items	Total Score	Validity Score
Learning	3	22	91,67%
Material	2	16	100%
Media Quality	3	22	91,67%
Language Usage	2	16	91,67%
Media Display	3	23	100%
Average		95,83%	

From the results of Table 4, each aspect of learning achieved a validity score from educators reaching 91.67%, the material aspect 100%, the media quality and language use aspects reaching 91.67% and the media display aspect reaching 100%, with an average of 95.83% which is very practical. This means that the interactive learning media can be used by students. In addition to the practicality of the media, there are also the results of the data normality test. The Normality Test is the result of the normality test of the pretest and posttest values of students' mathematical concept understanding abilities which is displayed in Table 5.

Table 5. Normality Test Results of the Mathematical Concept Understanding Ability Test

Class	Data	Sig	Sig level	Information
Experiment	Pretest	0,200	0,05	Normally Distributed
Control	Pretest	0,093	0,05	Normally Distributed
Experiment	Posttest	0,173	0,05	Normally Distributed
Control	Posttest	0,064	0,05	Normally Distributed

The normality test is used to determine whether the residual values being analyzed follow a normal distribution or not (Dini, 2022). The outcomes of the calculation of the normality test of students' mathematical ability to comprehend concepts using the Komogrov-Sminov method show that the probability value (sig) for the pretest and posttest shows the results of $r_{sign} > 0.05$, which means that the normality test data comes from a population with a normal distribution. Apart from the normality test, there is also a Table 7's homogeneity test as follows:

Table 6. Homogeneity Test of Students' Mathematical Concept Understanding Ability

Data	Sig	Sig Lever	Information
Pretest	0,331	0,05	Varians Homogen
Posttest	0,123	0,05	Varians Homogen

In Table 6, the results of the homogeneity test of the pretest and posttest of students' mathematical concept understanding ability using the Leven's Test with an achievement of 0.331 and 0.123 show results of more than 0.05 or sig > 0.05 from the conclusion that H_0 is approved but H_1 is denied, which implies that both data groups have homogeneous variances. Uji homogeneity is conducted to show that the differences observed in the parametric statistical test truly occur due to differences between groups, not as a result of differences within the groups. In addition to the priority test, there is also a hypothesis test on the capacity to understand mathematical ideas via the Independent Sample Test in Table 8 as followst:

Table 7. Results of the t-test of the pre-test and post-test scores of students' mathematical concept understanding abilities

Data	Sig	α	Decision
Pretest	0,055	0,05	H_0 Accepted
Posttest	0,000001	0,05	H_1 Accepted

Considering the outcomes of Table 7, the results obtained are probability (sig) α > 0.05, with a significance achievement of 0.055, meaning that there is no difference in increasing comprehension of mathematical ideas within the experimental class compared to the control class. Because there is no difference, the outcomes of the pretest score, the hypothesis used only uses the t-test on the sample. In addition to the outcomes of the pretest t-test, there are also the results of the t-test on the posttest by showing the results of the significance of the t-test is 0.000001, then the results are sig <0.05, meaning that H_1 is accepted and H_0 is rejected, the results of the hypothesis test data on the posttest data conclude that there is a difference in increasing the capacity to comprehend pupils' mathematical ideas in the experimental class with an increase in the ability to understand mathematical concepts of students in the control class. So that creating interactive educational materials is declared effective in improving the capacity to comprehend mathematical ideas for students. In addition to homogeneity, there are also the results of students' post-test achievement in terms of their capacity to comprehend mathematical ideas in table 9 as follows:

Table 8. Results of hypothesis testing through proportion tests

Data	Average	Criteria
Pretest	0,25	Quite effective
Posttest	0,33	Quite effective

According to Table 8, the results of the posttest comparing the experimental and control classes' capacity to comprehend mathematical ideas showed an increase after the treatment was carried out through jigsaw learning with the use of interactive media. On average, the control class had partially achieved an increase of above 60% or a standard value of 60 and there was a variation in the outcomes of the achievement of the experimental class and the control class after the use of jigsaw learning and the use of interactive media in the experimental class and the use of conventional studying in the control group.

The findings of this study indicate that the developed interactive learning media, integrated with the Jigsaw learning model, meets the standards of validity, practicality, and effectiveness. Based on expert assessments, the average material validation score reached 84%. According to Ardianti et al. (2022), a validity percentage between 80 and 100 indicates a high level of validity. This suggests that the material content, language, and evaluation aspects embedded in the media are appropriate for supporting students' understanding of mathematical concepts. Furthermore, the media validation based on assessments of visual design (87%) and functionality (77%) yielded an average score of 82%. In accordance with Supriadi (2021), media that achieves a score within the 0.800–1.000 range is considered highly valid, further confirming that the media met the expected quality standards in terms of appearance, usability, and instructional alignment.

The results of the normality and homogeneity tests also strengthen the reliability of the study. The pretest and posttest data from both control and experimental groups showed significance levels greater than 0.05, indicating that the data were normally distributed and the variance was homogeneous across groups. These findings validate the assumptions necessary for conducting further parametric analysis. The independent samples t-test for the pretest revealed no significant difference between groups (sig = 0.331 > 0.05), suggesting equivalence in initial ability. However, the posttest results demonstrated a significant difference (sig = 0.00 < 0.05), with $\mu 1 < \mu 2$, indicating that students in the experimental group who used the interactive learning media achieved better conceptual understanding compared to those in the control group. Thus, H1 is accepted and H0 is rejected, confirming the effectiveness of the developed media in improving students' mathematical concept comprehension.

These findings are consistent with previous research showing that media-integrated learning can enhance student engagement and cognitive development. For example, Saputra et al. (2018) and Ha & Im (2020) found that interactive learning tools can increase student motivation and support conceptual clarity through visual and exploratory features. Moreover, the cooperative structure of the Jigsaw model, emphasizing individual accountability and peer teaching has been shown to reinforce deeper understanding and collaborative learning outcomes (Akmalia & Cahyani, 2021; Steven & Slavin, 1995). The combination of Jigsaw and interactive media in this study proved to be a powerful pedagogical tool, enabling students not only to absorb material effectively but also to actively construct and apply knowledge.

Implication

The implications of this research are twofold. First, it demonstrates that the development of valid and practical instructional media, when aligned with student-centered pedagogical models like Jigsaw, can significantly improve learning outcomes. Second, it highlights the importance of ongoing evaluation in the development process, ensuring that learning tools remain relevant, engaging, and effective. Future research may consider extending this approach to different subject areas or educational levels, as well as exploring long-term retention and transferability of conceptual understanding.

Limitations of the Study

This study has several limitations that may influence the interpretation and generalization of its findings. The research was conducted in a single school with a relatively small number of participants, which may limit the applicability of the results to broader educational contexts (Giyanto et al., 2020). Although the interactive learning media was validated by content and media experts, this study did not explore other influential factors such as student motivation, classroom interaction, or teaching strategies, which can also affect learning outcomes. In addition, the media developed was only applied to mathematics content, and its effectiveness over time or in other subject areas has not been investigated. To build on this work, future studies should involve larger and more diverse samples, take into account various external variables, and examine the broader and long-term impacts of the learning media across different disciplines.

CONCLUSION

The results of this study conclude that the interactive learning media developed through the ADDIE model meets the criteria of validity, practicality, and effectiveness for mathematics instruction at the junior high school level. Based on expert evaluations, the media demonstrated high levels of validity, with average scores of 84% for material content, 92% for language, and 75% for evaluation components. Media design and operational aspects were also rated highly valid, averaging 82%. The practicality test results showed that the media is easy to use and well-received by students, with an average score of 88.54%, indicating its usability across a range of student ability levels. Statistical analyses confirmed that the pretest and posttest data were normally distributed and had homogeneous variances, supporting the reliability of the findings. Furthermore, the posttest results revealed a significant difference between the experimental and control groups, indicating that the integration of interactive media in mathematics instruction effectively enhances students' conceptual understanding. In light of these findings, the interactive learning media developed in this study can be considered a promising alternative to conventional instructional tools. It is particularly relevant for promoting active learning, increasing student engagement, and fostering deeper conceptual understanding in mathematics classrooms.

AUTHOR CONTRIBUTIONS STATEMENT

All authors contributed to the conception and design of the research.
RH : Conceptualization, writing original draft, formal analysis, methodology.
SH : Editing, and visualization.
SS : Visualization, review, and editing.

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