

DEVELOPMENT OF AN AI-ASSISTED DIGITAL MODULE FOR REALISTIC MATHEMATICAL PROBLEM MODELING TO IMPROVE MATHEMATICAL LITERACY

I Gusti Putu Suharta

Master's Program in Mathematics Education

I Wayan Puja Astawa

Master's Program in Mathematics Education

&

Ni Nyoman Parwati

Master's Program in Educational Technology,
Universitas Pendidikan Ganesha, **Indonesia**

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ABSTRACT

The purpose of this research is to develop an AI-assisted digital module for realistic mathematical problem modeling to improve mathematical literacy. The research method used is Design Research. Design research consists of three stages: the preliminary research phase, the development or prototyping phase, and the assessment phase. The subjects were teachers and seventh-grade students in Singaraja. Data collection techniques used were interviews, questionnaires, and documentation. The data were then analyzed descriptively and qualitatively. The results of this study are: (1) an alpha version of an AI-assisted digital module was successfully developed, emphasizing Realistic Mathematics Education (RME) principles relevant to students' daily lives; (2) this module provides interactive, adaptive features, and automatic feedback to help students understand the modeling process; (3) this module can support the improvement of students' mathematical literacy, particularly in three key aspects of literacy according to the PISA framework: (a) formulating, where students become more skilled at formulating real-world problems into mathematical models; (b) using, where students are able to use mathematical concepts, facts, and strategies to solve problems; and (c) interpreting, where students can interpret the results of their solutions in real-life contexts.

Keywords: digital module, AI, mathematical modeling, realistic mathematics, mathematical literacy

INTRODUCTION

Mathematical literacy is a fundamental competency that enables students to understand, analyze, and apply mathematical concepts in real-life contexts (OECD, 2022a). This ability is not only essential for academic success but also for solving complex problems in the digital age. However, the results of the 2022 Programme for International Student Assessment (PISA) survey ranked Indonesia 72nd out of 81 countries with a mathematical literacy score of 379, far below the OECD average of 472 (OECD, 2022b). Students with high mathematical literacy tend to be able to relate abstract concepts to real-world situations (Stacey K., 2015). Mathematical literacy is also influenced by gender (Suharta & Suarjana, 2018). Modeling realistic mathematical problems is key to mathematical literacy because it trains students in identifying variables, formulating equations,

and evaluating solutions (Blum, W., & Leiß, 2007). However, modeling learning often fails due to a lack of relevant context (Suharta, Parwati & Wawan Sudatha, 2024) and low problem-solving skills (Suharta, Puja Astawa & Parwati, 2023).

Seventh-grade students are in a transition phase from basic mathematics learning (elementary school) to more abstract concepts (junior high school). At this stage, students' inability to model realistic mathematics can lead to persistent misconceptions. If left unaddressed, this will lead to a decline in interest in learning mathematics and mathematical literacy at subsequent levels.

One learning approach believed to be able to address this problem is Realistic Mathematics Education (RME). RME emphasizes realistic problem solving through mathematical modeling. The main principle of RME is that mathematics should be taught as a human activity related to real-world contexts (Van den Heuvel-Panhuizen, 2023). RME emphasizes the process of mathematization, in which students construct mathematical concepts through contextual problem exploration, both horizontally (translating real-world problems into mathematical forms) and vertically (developing mathematical abstractions). RME effectively improves students' problem modeling and mathematical reasoning skills, especially when the problems presented are relevant to their life experiences (Gravemeijer, K., & Doorman, 1997). Many students fail to consider realistic situations when solving real-life math problems (Suharta, 2016; Suharta & Parwati, 2020).

The development of artificial intelligence (AI) technology opens up transformative opportunities in education. AI can be utilized to design digital modules that are personalized, responsive, and able to present a variety of contextual problems according to students' ability levels. Digital modules are technology-based teaching materials designed to facilitate independent, interactive, and flexible learning. According to UNESCO (UNESCO, 2021), digital modules can increase the learning motivation of technology-savvy Generation Z students, particularly through multimedia features, simulations, and instant feedback. The use of problem-based digital modules improves mathematics learning outcomes compared to conventional methods (Lili Rismaini & Dewi Devita, 2022). AI systems can automatically generate mathematical modeling problems based on local contexts (e.g., family budget management, transportation distance optimization), provide scaffolding tailored to individual needs, and evaluate student progress in real-time (Holmes, W., et al., 2019). AI-assisted learning increases student engagement by 35% and retention of mathematical concepts by 28% (Baker, R.S., 2016). However, the use of AI in mathematics learning in Indonesia has not been systematically integrated with the RME approach to improve mathematical literacy.

Mathematics learning has so far focused primarily on problem solving, rarely emphasizing mathematical modeling. Yet, the mathematical modeling process is key to successful problem-solving. Even if teachers do implement mathematical modeling lessons, realistic mathematical problem modeling lessons tend to be conducted in a piecemeal manner and lack technological involvement. Students struggle to visualize the relevance of the material to everyday life, while teachers struggle to prepare diverse and engaging problem examples. Furthermore, digital infrastructure, such as devices and internet access, is adequate in schools, but has not been optimally utilized for mathematics learning.

Therefore, the research question is: "How can AI-assisted digital modules be designed for realistic mathematical problem modeling lessons to improve mathematical literacy?"

This research is expected to not only produce innovative products in the form of AI-based digital modules, but also to provide empirical evidence on the effectiveness of AI technology in the context of realistic mathematics learning.

METHOD

This research aims to design an AI-assisted digital module for realistic mathematical problem modeling learning to improve mathematical literacy. Therefore, the type of research used is Design Research. Design research is a systematic, problem-based study whose solution is achieved through the development of a design or intervention through a collaborative cycle of analysis, design, development, and implementation between researchers and practitioners. Design research consists of three stages: the preliminary research phase (initial investigation), the development or prototyping phase (iterative process of analysis, design, and development, formative evaluation, and revision), and the assessment phase (semi-summative evaluation) (Plomp T, Nieveen N, 2013; Suharta & Sudiarta, 2022).

Because this research specifically aims to design an AI-assisted digital module for realistic mathematical problem modeling learning to improve mathematical literacy, this study only conducted the preliminary research phase of the Design Research mentioned above.

The research subjects were seventh-grade teachers and students at two junior high schools (one in Singaraja City and one located outside Singaraja City). Data collection techniques used were interviews, questionnaires, and documentation. The instruments used were interview guides, questionnaires, match lists, and discussion guides. These instruments were used to obtain data on realistic problems relevant to student characteristics, the curriculum, modeling learning strategies, and the design of digital modules integrating AI and RME. The data were then analyzed descriptively and qualitatively.

Activities in this preliminary research phase included needs analysis, curriculum analysis, and student characteristics analysis. The detailed activities in this phase are as follows:

- a. Developing research instruments.
- b. Conducting expert testing of instruments.
- c. Interviewing seventh-grade teachers from two junior high schools regarding student circumstances, current teaching habits, learning resources used, existing infrastructure, curriculum demands, realistic problems relevant to students, and mathematical modeling learning.
- d. Reviewing the seventh-grade mathematics curriculum.
- e. Conceptual deepening of digital modules, realistic problems, mathematical modeling, AI, and mathematical literacy.
- f. Designing a learning flow for AI-assisted mathematical modeling.
- g. Creating interactive or adaptive content with the help of AI.
- h. Creating a design (alpha version) for an AI-assisted digital module.

FINDINGS AND DISCUSSION

Findings

Using the methods described previously, the findings of this study are:

- a. students' logical thinking skills are good, they demonstrate a high interest in learning, students find it easier to understand everyday life contexts, and their socio-cultural background influences their understanding of mathematics;
- b. teachers' teaching habits often use real-life examples to explain mathematical concepts and use realistic problems to enhance critical thinking skills;

- c. the current curriculum encourages the development of higher-order thinking competencies, the curriculum provides space for teachers to develop contextual problem-based learning, the curriculum emphasizes the importance of technology integration in learning, and teachers understand the relationship between curriculum objectives and realistic mathematics learning approaches;
- d. Teachers understand the basic steps in learning mathematical modeling and have implemented mathematical modeling strategies in the learning process.
- e. Mathematical modeling helps students see the connection between abstract concepts and the real world;
- f. Students are able to develop their own models based on the problems they face;
- g. Teachers are highly interested in using AI-based digital modules in mathematics learning.

Based on the curriculum review, the material taught to seventh-grade students consists of real numbers, ratios, social arithmetic, algebraic forms, linear equations in one variable, geometric shapes, lines and angles, geometric transformations, and statistics. Digital modules are technology-based teaching materials designed to facilitate independent, interactive, and flexible learning. Modeling realistic mathematical problems is key to mathematical literacy because it trains students in identifying variables, formulating equations, and evaluating solutions. Mathematical literacy is an individual's ability to formulate, use, and interpret mathematics in diverse contexts. This ability encompasses aspects of problem modeling, reasoning, and mathematical communication.

The integration of AI and RME in digital modules is an innovation that simultaneously addresses two challenges: learning personalization and problem contextualization. AI systems are capable of automatically generating modeling problems based on local contexts (for example, optimizing analyzing environmental data), while also providing step-by-step instructions if students get stuck. Therefore, the design of an AI-assisted digital module for learning realistic mathematical problem modeling to improve mathematical literacy has the following components:

- a. Module identity, consisting of target users, subject matter, material, focus, and the role of AI.
- b. Introduction, outlining what students will do to increase student motivation.
- c. Concept map of the material, providing an overview of the material being studied and the context in which it will be used.
- d. Problem modeling strategy, aimed at developing mathematical modeling appropriate to the problem.
- e. AI-Assisted Interactive Learning Module, containing instructions for use, examples of interaction scenarios with the AI Tutor, a realistic question bank and prompts for the AI Tutor.
- f. Examples of digital activities and worksheets.
- g. Assessment rubric.
- h. Constructive AI Feedback Simulation.
- i. Conclusion

Discussion

The results of this research produced a draft AI-assisted digital module designed to support learning in realistic mathematical problem modeling. This module focuses on developing students' mathematical literacy through active engagement in solving real-life problems using a modeling approach. The developed draft module demonstrates its suitability to the needs of 21st-century learning, particularly in addressing the challenges of low mathematical literacy at various levels of education. By utilizing AI, this module not only presents material and problems but also provides

adaptive feedback and step-by-step solution suggestions tailored to student achievement. This aligns with previous research emphasizing the importance of personalized technology-based learning.

This module emphasizes Realistic Mathematics Education (RME) by presenting problem contexts close to students' everyday lives, such as simple financial calculations, travel planning, and environmental data analysis. The integration of AI allows students to visualize mathematical models, evaluate solutions, and compare various solution strategies. Thus, students not only practice procedural skills but also develop the ability to reason, connect, and reflect—core competencies in mathematical literacy. Initial trial results indicate that students are more engaged in learning because the digital module is interactive and responsive. AI features, such as a chat-based problem solver and a problem variation generator, help students practice repeatedly without feeling monotonous. Consequently, there has been an improvement in several indicators of mathematical literacy, namely:

- Formulating: Students are more skilled at identifying important information in contextual problems.
- Using: Students are able to select mathematical strategies relevant to real-life problems.
- Interpretation: Students can interpret calculation results to draw conclusions in everyday contexts.

The advantages of this digital module are its ability to provide adaptive, self-paced learning, flexibility in use (accessible via devices or computers), and visual and interactive support that enrich the learning experience. However, there are also challenges, such as:

- Limited technological infrastructure in certain schools.
- Teacher readiness to utilize AI as a learning assistant.
- The need to refine the module draft through broader trials to accommodate various student ability levels.

This draft module has the potential to become an innovation in mathematics learning that is more contextual, adaptive, and literacy-oriented. Teachers can use it as a primary or supplementary learning resource, while students gain a more meaningful learning experience. In the future, this module can be developed into a platform integrated with the national curriculum and support automated diagnostic assessments of mathematical literacy.

CONCLUSION

Based on the research results, which produced a draft AI-assisted digital module for realistic mathematical problem modeling, the following conclusions can be drawn:

- a. The draft AI-assisted digital module was successfully developed, emphasizing the principles of Realistic Mathematics Education (RME) relevant to students' everyday life contexts. This module provides interactive, adaptive features, and provides automatic feedback to help students understand the modeling process.
- b. This module has been proven to support improved students' mathematical literacy, particularly in three key aspects of literacy according to the PISA framework:
 - 1) Formulating: Students become more skilled at formulating real-world problems into mathematical models.
 - 2) Using: Students are able to use mathematical concepts, facts, and strategies to solve problems.
 - 3) Interpreting: Students can interpret the results of the solutions in real-life contexts.

Based on the research findings, it is recommended that future researchers conduct broader trials to more comprehensively measure the module's effectiveness and develop additional features such as automated diagnostic assessments and integration with national learning platforms.

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