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Development of Mathematics Learning Design Using AI-Based Deep Learning Approach to Enhance Students' Digital Literacy

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Abstract

The deep learning approach has been introduced as a new governmental strategy to improve the quality of education in Indonesia and is currently being implemented in the national curriculum. However, there remains a lack of research that holistically develops deep learning instructional designs integrated with Artificial Intelligence (AI) to support students' digital literacy. Therefore, the development of a mathematics instructional design that synergistically combines deep learning and AI-based technology to enhance digital literacy is still an unmet educational need. This study aimed to develop a mathematics learning design using an AI-based deep learning approach to improve students' digital literacy, specifically in the topic of three-dimensional geometric shapes for Grade V elementary students. The study employed a Research and Development (R&D) method following the ADDIE development model: Analysis, Design, Development, Implementation, and Evaluation. The result of this study is a mathematics learning design using AI-based deep learning approach in the topic of elements and nets cube and cuboid. The teaching module was validated as highly valid, with a validation score of 3.64, and found to be highly practical with a practicality score of 3.39. Furthermore, the design was proven effective in improving digital literacy, as shown by a significant difference between students' pre-test and post-test scores based on the Wilcoxon Signed Rank Test (Z = -3.051, Asymp. Sig. (2-tailed) = 0.002). The average digital literacy score increased from 29.35 (pre-test) to 32.55 (post-test), indicating that the instructional design had a significant positive impact on students' digital literacy. Through this learning design, students experienced deep learning that emphasized understanding, application, and reflection through mindful, meaningful, and joyful learning activities. This research contributes to the advancement of mathematics education by offering a holistic mathematics learning design using AI-based deep learning approach which effective in enhancing students' digital literacy.

Keywords: Mathematics Learning Design; Deep Learning Approach; Artificial Intelligence; Digital Literacy

Abstrak

Pendekatan deep larning sebagai suatu strategi baru pemerintah dalam meningkatkan kualitas pendidikan di Indonesia dan mulai diterapkan di kurikulum yang saat ini berlaku. Akan tetapi, belum banyak penelitian yang mengembangakan desain pembelajaran deep learning secara holistik dengan berbasis Artificial Intelligence (AI) yang mendukung literasi digital siswa. Sehingga pengembangan desain pembelajaran matematika yang mengintegrasikan pendekatan pembelajaran deep learning dan teknologi berbasis AI secara sinergis untuk meningkatkan literasi digital siswa masih menjadi kebutuhan yang belum terjawab. Penelitian ini bertujuan untuk mengembangkan desain pembelajaran matematika dengan pendekatan deep learning berbasis AI sebagai upaya untuk meningkatkan literasi digital siswa, khususnya pada materi bangun ruang sisi datar kelas V SD. Penelitian ini menggunakan metode penelitian Research and Development (R&D) dengan model pengembangan Analysis, Design, Development, Implementation, dan Evaluation (ADDIE). Penelitian ini menghasilkan desain pembelajaran matematika dengan pendekatan deep learning berbasis AI berupa modul ajar materi unsur-unsur dan jaring-jaring kubus dan balok untuk kelas V SD yang terbukti valid dengan skor validasi 3.64 (sangat valid), terbukti praktis dengan skor kepraktisan 3.39 (sangat praktis). Desain pembelajaran yang dikembangkan juga *terbukti efektif meningkatkan literasi digital siswa melalui Wilcoxon Signed Rank Test pada nilai pre tes dan pos tes angket literasi digital siswa dengan Z = -3.051 dan Asymp. Sig. (2-tailed) = 0.002, sehingga terdapat perbedaan yang signifikan antara literasi digital sebelum dan setelah pembelajaran matematika dengan pendeketan deep learning berbasis AI dilakukan. Rata-rata skor literasi digital siswa meningkat dari 29.35 pada pre tes literasi digital menjadi 32.55 pada pos tes literasi digital siswa sehingga penerapan desain pembelajaran mampu memberikan dampak positif yang signifikan terhadap literasi digital siswa. Melalui desain pembelajaran ini, siswa mendapatkan pengalaman belajar memahami, mengaplikasi, dan merefleksi melalui pembelajaran berkesadaran, bermakna, dan menggembirakan. Penelitian ini memberikan kontribusi dalam perkembangan pembelajaran matematika dalam hal pengembangan desain pembelajaran matematika dengan pendekatan deep learning secara holistik serta berbasis AI yang efektif dalam meningkatkan literasi digital siswa.*

Mathematics Clasification: 97U10 Comprehensive works on educational material and media and educational technology in mathematics education

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INTRODUCTION

Deep learning refers to the ability to grasp and integrate conceptual and procedural knowledge, along with applying conceptual insights in unfamiliar contexts (Hattie & Donoghue, 2016; Miller & Krajcik, 2019). The implementation of a deep learning approach in education must be supported by several key factors, including a conductive learning ecosystem, broad and meaningful learning partnerships, and the effective integration of digital technology (Suyanto et al., 2025). The components are essential to realizing the three core principles of deep learning: mindful learning, meaningful learning, and joyful learning. When these principles are applied effectively, the deep learning approach can significantly enhance students' competencies, foster their learning interest and awareness, and encourage active participation in the learning process (Kong & Hao, 2022).

The implementation of the deep learning approach in education represents the government's commitment to accelerate educational transformation, as well as to enhance and expedite the impact of education in preparing a generation to achieve the demographic dividend in 2025 and the Golden Indonesia vision in 2045. The Head of Primary and Secondary Education Ministry, stated in Tempo (2024) that this approach has been integrated into the learning process through the curriculum currently implemented within the national education system. However, the readiness of teachers to adopt and implement the deep learning approach is still considerably low (Atmojo et al., 2025), posing a challenge to its effective integration into educational practice.

In the implementation of the deep learning approach, it is essential for teachers to comprehend the effective integration of digital technology in the learning process, as it constitutes a key supporting component of deep learning. One of the technological applications that can be integrated into the learning process is the use of digital learning media and Artificial Intelligence (AI). AI, in particular, can contribute significantly to improving instructional quality, enriching learners' experiences, and deepening students' comprehension of subject content (AlAli & Wardat, 2024; Chen et al., 2020; Pokrivcakova, 2019; Sharma et al., 2019). The integration of Artificial Intelligence (AI) in education can play a pivotal role in achieving the Sustainable Development Goals (SDGs) by 2030, as well as the realization of the fourth Asta Cita, which emphasizes the government's commitment to reinforce national development, particularly in the domains of technology and education. The integration of technology in education is connected to students' digital literacy, defined as their ability to effectively engage with digital learning resources (Gilster, 1997; Makhafola et al., 2025). As a global concern, digital literacy must be developed in learning to prepare students for the demands and challenges of the 21^{st} century.

The development of IT- and AI-based mathematics learning has been explored in various studies, such as the study by Nadjla (2024) on AI-based mathematics learning found that the integration of Artificial Intelligence in mathematics instruction was effective in enhancing students' conceptual understanding, mathematical problem-solving skills, educational accessibility, and character development. Furthermore, research has been conducted on teachers' experiences with AI-based instructional tools (Arvin et al., 2023), as well as exploratory study on teachers' perceptions, challenges, and the pedagogical implications of integrating AI-based ChatGPT into mathematics learning (Egara & Mosimege, 2024). The findings of both studies indicate that AI is still rarely utilized in classroom practice, despite its demonstrated positive impact on teaching effectiveness, student engagement, and conceptual understanding. Realizing the full potential of AI in education requires improved digital literacy and teacher preparedness, supported by comprehensive implementation guidelines (Arvin et al., 2023). Subsequent research on mathematics education utilizing the deep learning approach remains limited in its integration with IT and AI. For example, the study conducted by Wijaya, et al (2025) applied the deep learning approach at the elementary school level. The main findings indicated that the deep learning approach was successful and had a positive impact on students' critical thinking skills, character development, social abilities, and learning motivation.

A review of existing studies reveals a research gap that has yet to be thoroughly explored. The study by Wijaya, et al (2025), for instance, focuses on the deep learning approach but does not holistically develop an AI-based deep learning instructional design. Meanwhile studies by Egara & Mosimege (2024), Arvin, et al. (2023), and Nadjla (2024) are relevant to the use of AI, yet remain limited in scope and do not comprehensively integrate AI-based deep learning instructional design with students' digital literacy. Moreover, previous research has primarily focused on the use of digital technologies such as applications and interactive learning media (Bray & Tangney, 2017; Reinhold et al., 2020). There is still a limited number of studies that holistically develop instructional designs based on advanced technologies, such as AI, to support students' digital literacy. Research on deep learning and AI in education has also not explicitly examined their contributions to enhancing students' digital literacy (Nababan et al., 2025). Consequently, the role of AI in creating learning experiences that improve digital literacy is still not widely discussed. Furthermore, mathematics learning, deep learning approaches, and AI-based educational technology are often studied separately (Barokah & Mahmudah, 2025).

Based on relevant previous research described, the development of an integrated mathematics instructional design that combines deep learning approaches and AI-based technologies to enhance students' digital literacy represents a critical and underexplored area of research. State of the art of this research are: a) comprehensive mathematics learning design with an AI-based deep learning approach; b) involving AI (ChatGPT) in mathematics learning linked to students' digital literacy; c) integrating mathematics learning design with a deep learning approach, AI, and 21^{st} century digital literacy needs.

The objective of this study is to develop a mathematics learning design that integrates an AI-based deep learning approach to enhance students' digital literacy, with a focus on the topic of three-dimensional geometric shapes for fifth-grade elementary students. This topic was selected due to its inherent need for interactive visualizations, which can be effectively facilitated through the use of digital technology and AI. Preliminary observations conducted at SD Muhammadiyah 15 Surabaya indicate that students encounter difficulties in understanding this topic, and that AI-based technological tools have not yet been utilized to support students' conceptual understanding. By integrating AI technologies and interactive digital media, the proposed mathematics learning design is expected to not only improve students' digital literacy, but also offer teachers an innovative alternative for implementing deep learning approaches within mathematics learning.

METHOD

This research used the Research and Development (R&D) research method with the ADDIE development model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. The Analysis stage included analysis of students' learning needs, and analysis of teacher needs and human resources. The Design stage included determining the materials used, determining the learning objectives, developing a teaching module framework, and determining the AI tools to be utilized. In the Development stage, learning media were prepared using AI-integrated GeoGebra with ChatGPT and a mathematics teaching module was developed using an AI-based deep learning approach focused on three-dimensional geometric shapes especially cube and cuboid. This stage also encompassed the development of research instruments, validation of the learning design, materials, and learning evaluation by experts, and validation and reliability testing of the students' digital literacy pre-test and post-test questionnaires by distributing the questionnaires to students who were not research subjects, namely 25 students of MI Roudlotul Mu'allimin Laban Menganti Gresik. The Implementation stage included pre-test for student digital literacy, implementation of the developed learning design, and post-test for student digital literacy. The Evaluation stage included distributing student response questionnaires and evaluating teaching module based on the results of the students' response questionnaires.

This research was conducted in July 2025 at SD Muhammadiyah 15 Surabaya, involving 20 fifth-grade students as research subjects. The AI utilized in this study was Generative Pre-trained Transformer (ChatGPT), which was integrated with the IT-based learning media GeoGebra. The use of GeoGebra aimed to facilitate interactive simulations of the elements and nets of three-dimensional geometric spaces, especially cube and cuboid. Meanwhile, the ChatGPT features employed in the developed learning design included mathematical concept explanations, an interactive question-and-answer assistant, critical thinking stimulation through reflective questioning, provision of independent practice exercises, and assistance in operating GeoGebra.

The data collection techniques in this study such as: a) observation; b) interviews, to analyze the needs of teachers and students, and analyze teacher human resources; and c) questionnaires, student responses questionnaires to practicality test and digital literacy pre-test and post-test questionnaires to effectiveness test.

Data analysis techniques used in this study included validity test analysis, practicality test analysis, and effectiveness test analysis. The validity of the learning design, materials, and learning evaluation was analyzed based on the validity mean score obtained for each indicator, using the following formula:

$$\overline{x_v} = \frac{Total\ Score}{Number\ of\ Indicators}$$

The validity mean score was grouped into four validity criteria (Hobri, 2021), as shown in Table 1 below.

Table 1. Validity Criteria

Validity Mean Score ($\overline{x_v}$)	Validity Criteria
$3.25 < \overline{x_v} \leq 4.00$	Very Valid
$2.50 < \overline{x_v} \leq 3.25$	Valid
$1.75 < \overline{x_v} \leq 2.50$	Less Valid
$0 \leq \overline{x_v} \leq 1.75$	Not Valid

The learning design, materials, and learning evaluation were feasible for implementation in research if the average score for each criterion was very valid or valid.

Meanwhile, practically analysis was obtained through student response questionnaires. Practicality can be seen from the practicality mean score obtained for each indicator using the following formula:

$$\overline{x_p} = \frac{Total\ Score}{Number\ of\ Indicators}$$

The practicality mean score was grouped into four practicality criteria (Hasanah et al., 2023), as shown in Table 2.

Table 2. Practicality Criteria

Practicality Mean Score ($\overline{x_p}$)	Practicality Criteria
$3.25 < \overline{x_p} \leq 4.00$	Very Practical
$2.50 < \overline{x_p} \leq 3.25$	Practical
$1.75 < \overline{x_p} \leq 2.50$	Less Practical
$0 \leq \overline{x_p} \leq 1.75$	Not Practical

Furthermore, to analyze the effectiveness of enhancing digital literacy, a one-group pre-test post-test comparison experimental design was used. Differences in average pre-test and post-test digital literacy scores were analyzed using Wilcoxon Signed Rank Test since based on the normality test with the Shapiro-Wilk test, it was found that the data was not normally distributed.

RESULTS AND DISCUSSION

Results

The stages in the development of a mathematics learning design using deep learning approach based AI are described as follows.

Analysis Stage

At this stage, a need analysis is conducted to identify teachers' challenges in delivering mathematics material, as well as students' difficulties in understanding mathematical concepts. Additionally, an analysis of teacher competencies is carried out, particularly regarding their understanding of mathematics learning through a deep learning approach. Based on interviews with selected students and teachers at SD Muhammadiyah 15 Surabaya, the following empirical data were obtained: (a) mathematics learning has not fully implemented the deep learning approach; (b) teachers' knowledge of deep learning is limited, often perceived merely as an extension of contextual learning; (c) technology-based instructional media are rarely used, as technology is perceived to have minimal impact on students' comprehension; (d) AI has never been utilized in instructional practices; and (e) students perceive mathematics learning environments as monotonous and unengaging.

Design Stage

At design stage, researchers determine the learning material, specifically focusing on the elements and nets of three-dimensional geometric shapes, namely cube and cuboid. Researchers develop the framework for the teaching module, which includes the design of its components as follows: (a) the identification section, comprising student identification, subject matter identification, and graduate profile dimensions; (b) the learning design section, which consists of learning outcomes, interdisciplinary connections, learning topics, learning objectives, pedagogical practices, learning partners, learning environment, and digital integration; (c) the learning experience section, detailing the steps of learning activities; and (d) the assessment section, which encompasses assessments of learning, assessments as learning, and assessments for learning.

At this stage, researchers also select the AI technology to be integrated into learning process, aligning with the principles of the deep learning approach. ChatGPT is chosen with the objective of providing immediate feedback to students, personalizing learning based on individual student needs, and enhancing interactivity by incorporating advanced and cutting-edge technology. In line with research by Egara & Mosimege (2024), which indicates that ChatGPT has a positive impact on learning effectiveness, student engagement and comprehension.

Development Stage

At the development stage, researchers prepare ChatGPT-integrated learning media using GeoGebra to be utilized in learning activities. The learning media employed have passed both validity and practicality tests. Furthermore, researchers develop a teaching module using AI-based deep learning approach for teaching three dimensional shape (cube and cuboid) for fifth-grade elementary students, aiming to enhance students' digital literacy. This development process includes the design of the module's cover, layout, and content.

The teaching module consists of several components: lesson plans, pretest and posttest on material and digital literacy, student worksheets for the topic elements and nets of cube and cuboid, student reflective journals, self-assessment sheets, and peer-assessment sheets. The cover design of the teaching module is illustrated in Figure 1 below.

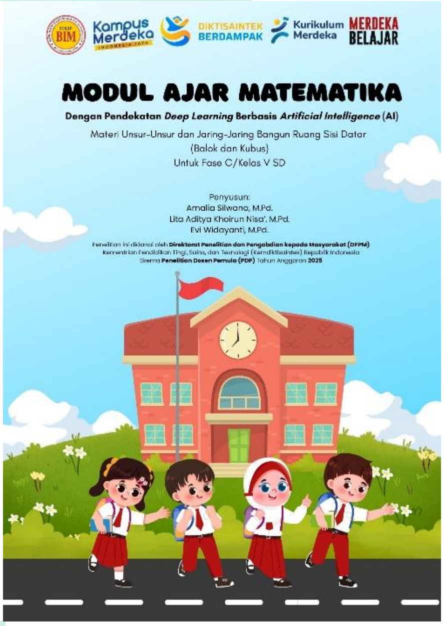

Figure 1. Cover of Mathematics Teaching Module.

At this stage, the validity and reliability of the digital literacy pretest and posttest questionnaire were tested by distributing the questionnaire to students who were not research subjects, namely 25 students of MI Roudlotul Mu'allimin Laban Menganti Gresik. The validity test of the digital literacy pretest and posttest questionnaire is presented in Table 3 below.

Table 3. Validity Test Result

Statement	Calculated r Value	Table r value	Criteria
P1	0.446	0.3961	Valid
P2	0.427	0.3961	Valid
P3	0.399	0.3961	Valid
P4	0.475	0.3961	Valid
P5	0.741	0.3961	Valid
P6	0.527	0.3961	Valid
P7	0.473	0.3961	Valid
P8	0.464	0.3961	Valid
P9	0.401	0.3961	Valid
P10	0.455	0.3961	Valid
P11	0.473	0.3961	Valid

Based on the validity test result in Table 3, all of the calculated r value for every items is greater than the r table value. Therefore, the 11 items in the digital literacy pretest and posttest questionnaires are considered valid. Next, a reliability test was conducted. The results of reliability test by SPSS obtained Cronbach's Alpha value 0.661. This value is greater than 0.6, indicating that the questionnaire is reliable. Since the digital literacy pre-test and post-test questionnaire has passed validity and reliability tests, it can be used to measure digital literacy level in research.

Furthermore, the validity of teaching module was tested by three experts: learning design expert, material expert, and learning evaluation expert. The validity test by the learning design expert about compatibility of learning objectives, compatibility of materials and learning design, learning steps, appropriateness of technology integration, relevance of digital literacy enhancement, and coherence of design component obtained an average validation score of 3.45. The validity test by the material expert about compatibility of material with learning outcomes, material accuracy (scientific quality and conceptual precision), meaningfulness of material and learning context, compatibility with deep learning approach, integration of technology and AI, language use and presentation obtained an average validation score of 3.83. The validity test by the learning evaluation expert consisted of validation of the material pre-test and post-test, student worksheets, student reflective journals, student self-assessment, and peer assessment obtained an average validation score of 3.65. Hence, the average score from overall validation results given by the three validators is 3.64, indicating a high level of validity (Hobri, 2021). Thus, the teaching module is considered appropriate for use in this study.

Implementation Stage

In the implementation stage, a trial of the mathematics learning design developed over five meetings was conducted. At the beginning of the lesson, students completed a digital literacy pretest questionnaire, and at the end of the lesson, they completed a digital literacy posttest questionnaire. The results of the digital literacy pretest and posttest were used to determine the effectiveness of the learning design in improving students' digital literacy.

Based on SPPS analysis result, the mean digital literacy score of students before being given mathematics learning according to the developed learning design was 29.35 and after being given mathematics learning according to the developed learning design was 32.55 or an increase in the mean score of 3.2. Furthermore, the pretest and posttest scores were compared to determine whether there were significant differences in students' digital literacy before and after the implementation of the developed learning design.

However, before being compared, the data scores were first tested for normality. Based on the SPSS output, the Shapiro-Wilk Significance value for the digital literacy pretest is 0.030. If the significance level used 5%, then Sig. < 0.05. So, the digital literacy pretest data is not normally distributed. While the Shapiro-Wilk significance value for the digital literacy posttest is 0.307. Then Sig. > 0.05. So the digital literacy posttest data is normally distributed. Therefore, the test for differences between the digital literacy pretest and posttest scores uses a non-parametric test, namely the Wilcoxon Signed Rank Test. Testing the null hypothesis that there is no significant difference in students' digital literacy in mathematics learning with deep learning approach based AI using SPSS. Based on SPSS output, sixteen students obtained higher posttest scores than their pretest scores. Meanwhile, four students' posttest score decreased.

Null hypothesis testing was continued using the Wilcoxon Signed Rank Test. Based on the test results obtained Z= -3.051 and Asymp. Sig. (2-tailed) = 0.002. By using significance level of 5%, Asymp. Sig. (2-tailed) < 0.05 which means H_0 is rejected so that there is a significant difference between digital literacy before and after mathematics learning with deep learning approach based AI is carried out. This shows that the developed learning design has proven effective in improving students' digital literacy.

Evaluation Stage

In the evaluation stage, students completed a student response questionnaire to determine their responses to the developed learning design. The results of the student response questionnaire were used to test the practicality of the developed learning design and evaluate the teaching module. The results of the practicality test for every aspect: the average score for attractiveness of the learning process aspect is 3.33; the average score for meaningfulness of the learning process aspect is 3.58; the average score of presentation of learning materials aspect is 3.38; and the average score of learning materials aspect is 3.25. Hence, the average total score of practicality test result is 3.39, indicating a high level of practical (Hobri, 2021).

Discussion

The mathematics learning design for the topic of elements and nets of cubes and cuboid was developed using a holistic deep learning approach, in accordance with the deep learning framework proposed by the Ministry of Primary and Secondary Education (Suyanto et al., 2025). The developed learning design is structured to facilitate in-depth exploration of the subject matter through activities grounded in the principles of mindful, meaningful, and joyful learning, aiming to foster experiences of understanding, application, and reflection. This aligns with the core goals of deep learning, which include promoting deep conceptual understanding (Rahayu et al., 2025), encouraging student participation through interactive activities (Mutmainnah et al., 2025), fostering long-term knowledge construction (Bistari et al., 2025), strengthening skills aligned with real-world demands (Akmal et al., 2025), and stimulating students' creative thinking in developing ideas for their projects (Natsir, 2025).

The first step in developing a deep learning-based lesson plan is identification, which includes identifying students, identifying materials, and determining the dimensions of the graduate profile. The determination of the graduate profile dimensions is carried out by aligning them with the intended learner outcomes expected upon completion of the learning process. In this instructional design, five dimensions of the graduate profile are selected: (1) critical reasoning, as the learning activities presents students with problems and task that require critical thinking skills; (2) creativity, as the lesson involves project-based tasks that demand students' creative thinking; (3) collaboration; as group-based activities are incorporated throughout the learning process; (4) independence, as despite the collaborative learning, there are tasks that require individual responsibility and self-direction; and (5) communication, as the learning process cultivates communication skills through inter-group discussion, classroom presentations, participation in whole-class discussion, and written self-reflection in reflective journals. The selected graduate profile dimensions are aligned with the learning culture promoted in this design, which emphasizes collaboration, active participation, critical thinking, and student curiosity.

In addition, this learning design introduces novel elements that differentiate it from other instructional approaches, namely the integration of interdisciplinary content and the involvement of learning partners. The interdisciplinary aspect in the developed mathematics learning design includes the integration of art and culture subject (in terms of the application of the material in everyday life) and information and communication technology (ICT) (as students engage in digital-based learning activities using tools such as AI-powered ChatGPT and GeoGebra as a digital learning media). Learning partners represent a key element of deep learning (Fullan & Quinn, 2020). In this design, art and culture teacher is invited as learning partner to provide students with additional knowledge on constructing cubes and cuboids, and to support them in completing a project by creating simple 3D models. The presence of learning partners can broaden students' perspectives and enhance the relevance and authenticity of the learning experience (Fullan et al., 2018).

The instructional models employed in this mathematics learning design are Discovery Learning for teaching the topic of the elements of cube and cuboid, and Project Based Learning for teaching the topic of cube and cuboid nets. Both instructional models are considered aligned with the principle of deep learning, because in these instructional models, the teacher as an activator and students are involved in choices and are responsible for their learning by involving students in authentic and relevant problems or simulations, thus demonstrating a deep learning process (Fullan et al., 2018).

The mathematics learning design with deep learning approach based AI that has been developed has undergone a validity assessment by experts in learning design, materials, and learning evaluation, yielding a score of 3.64, indicating a very high level of validity. Several improvement notes were provided by the validators including revisions to the layout design of the student worksheet to make them more appealing to fifth-grade elementary students, refinement of the pre-test and post-test content, and the addition of self-assessment and peer-assessment items related to students' ability to use AI tools. This aligns with previous research, which emphasizes that student worksheets should be designed to e visually engaging (Wahyuni et al., 2021). Furthermore, colour selection in design has been shown to influence students' behaviour, emotional responses, and learning success at the elementary school level (Glogar et al., 2017).

The developed mathematics learning design has proven to be practical, as indicated by a high practicality score (3.39) based on aspects of learning attractiveness, usefulness, and the quality of content and its delivery. Mathematics learning using a deep learning approach offers students a unique and meaningful experience. In line with the principle of deep learning, students are guided to be consciously aware of the intended learning goals from the outset, experience the benefits of learning because the content is connected to their daily lives, and are encouraged to think critically about societal conditions and how mathematical concepts can be applied in real-life contexts. This process leads to meaningful learning experience. Students are most engaged when what they are learning holds relevance beyond the classroom (Fullan & Langworthy, 2013). Through the project of constructing a simple 3D model, students are able to perceive the relevance and real-world application of the mathematical content.

Students are also encouraged to engage in self-reflection regarding the concepts they have understood and those they have not yet mastered, as well as to improve their performance in subsequent lesson as part of learning experience of reflection. In the developed mathematics learning design, for each sub-topic covered students are provided with a reflective journal. This journal is an integral component of mindful learning. It consists of several guided questions that students are required to answer. The questions follow the STARR reflection model, which includes: Situation (S) of the learning context; Task (T), the task students were assigned; Action (A), the actions taken to complete the tasks; Result (R), the outcomes of students' work, and Reflection (R), students' evaluation of learning process. This approach align with the STARR reflection model as discussed by Badriah & Permana (2023). This kind of reflection model has proven effective in supporting the self-reflective process. Reflection is particularly crucial in mathematics education (Lee, 2021), as it allows students to revisit prior thinking, connect experiences with learning, and foster deep learning (Dewey, 1993).

The mathematics learning design with deep learning approach based AI has been proven effective in enhancing students' digital literacy. This learning design incorporates AI tools, specifically ChatGPT, along with the use of GeoGebra as an interactive and engaging digital mathematics learning media. Such integration aligns with the principles of the deep learning that emphasize meaningful and joyful learning experiences. AI has been shown to make learning more engaging and creative (Mohamed et al., 2022), which supports the joyful learning principle. Moreover, the use of AI-powered chat bots in education has the potential to advance the role of technology in learning and increase accessibility for all students regardless of their learning pace (Chau et al., 2025). In addition, the integration of digital technologies contributes to improvements in student performance, motivation, and problem-solving abilities (Rodríguez-Jiménez et al., 2023).

The use of GeoGebra as an instructional media includes interactive features that generate three-dimensional simulations of cube and cuboid, thereby facilitating students' understanding of the concepts. The interactive features in the learning media also serve to motivate students to participate more actively in learning process (Sinaga et al., 2022). In addition, the integration of technology in education is essential for improving the quality of instruction (Bayne, 2015; Hussin, 2018), making mathematics more accessible and flexible for diverse types of learners (Gadelha, 2018), and ensuring a more effective and efficient learning process (Ilyas et al., 2023). Technology has also been shown to increase students' motivation and willingness to engage in learning activities (Cóndor-Herrera et al., 2021). In the context of Indonesia's Merdeka Curriculum, the use of digital technology is considered a fundamental infrastructure need (Sari et al., 2024) and a critical component in implementing deep learning. Digital technologies can accelerate the process of deep learning (Fullan & Langworthy, 2014).

Furthermore, the use of AI in this study was found to have a positive impact on students, as evidenced by the increase in the average post-test scores of students' digital literacy. This finding is consistent with previous research, which has shown that AI offers several advantages, including enhancing conceptual understanding, improving student performance, and making learning more effective (Mohamed et al., 2022). The findings of this study also reveal that the use of AI-powered ChatGPT engaged students' creative thinking skills, particularly in generating prompts. Students were able to formulate prompts based on what they wanted to explore. For several question listed in student worksheet, students were instructed to gather information from the internet, particularly using ChatGPT. All five student groups submitted different prompts. In this context, it is essential for teachers to guide students in using AI effectively to support learning. AI should not merely be used to solve problems directly; rather, it should be employed to facilitate learning experiences. Therefore, teachers must provide instructional direction on how to make meaningful prompts in order to optimize AI interaction while ensuring alignment with learning objectives (Setälä et al., 2025).

The assessment methods employed in this learning design include assessments at the beginning, during, and at the end of the learning process. Assessments at the beginning of learning consist of a pre-test on the subject matter and a pre-test on digital literacy. Assessments during the learning process are student worksheets and a simple 3D model project. Assessments at the end of learning process are reflective journals, self-assessment, peer assessment, a post-test on the subject matter, and a post-test on digital literacy.

The assessments employed in this learning design align with the three primary functions of assessment: assessment as learning, assessment for learning, and assessment of learning. Assessment as learning refers to assessments aimed at supporting student reflection and learning reflection. In this design, it is implemented through reflective journals, student self-assessments, and peer assessment. In the context of deep learning, students are expected to reflect on their own understanding and learning processes (Fauskanger & Bjuland, 2018). Assessment for learning serves as a tool to improve the learning process by providing feedback for students and serving as a basis for teacher reflection. In this design, it takes the form of diagnostic question asked during whole-class reflection at the end of each learning meeting. Assessment of learning is used to evaluate students' learning achievements. In this design, it includes written tests and project-based assessments. The tasks provided in this learning design follow a constructivist orientation. High-quality deep learning tasks emphasize the application of newly acquired knowledge in real-world contexts

(Fullan & Langworthy, 2014).

Based on the explanation above, the mathematics learning design using AI-based deep learning approach has been proven to be valid, practical, and effective in enhancing students' digital literacy. Overall, the results of this study emphasize the importance of implementing deep learning approaches and integrating technology into mathematics education in a comprehensive manner. The combination of deep learning with digital technology integration (AI-based ChatGPT and GeoGebra) has led to improved students' digital literacy, increased engagement in learning, and deeper conceptual understanding. The results also highlight several strengths of implementing the developed mathematics learning design using AI-based deep learning approach: it aligns with the principles of mindful, meaningful, and joyful learning; provides an innovative instructional model for teachers to adopt; promotes active, personalized, adaptive, and differentiated learning; enhances flexibility and effectiveness in the learning process; develop 21st-century skills; and leverages a variety of digital learning resources.

Implication of Research

The successful development of mathematics learning design using AI-based deep learning approach has several important implications for mathematics education, particularly for education practitioners, school administrators, policymakers, and educational researchers aiming to enhance students' digital literacy. The effectiveness of the developed mathematics learning design in the form of a teaching module grounded in an AI-based deep learning approach demonstrated its feasibility in increasing student engagement, improving the quality of mathematics learning, and supporting students in developing their digital literacy skills. The learning design encourages students to become critical and creative thinkers, capable of effective collaboration and communication. Therefore, teachers and researchers are encouraged to adopt and further develop holistic mathematics learning designs based on deep learning approaches. They may also be inspired to integrate cutting-edge digital technologies and real-life, project-based learning tasks to foster deep and meaningful learning experiences. For school administrators and policymakers, the success of this learning design emphasize the importance of providing institutional support and infrastructure necessary for implementing digital innovations in classroom settings.

Limitation

This research has several limitations. The first limitation lies in the scope of the learning design developed, which was restricted to an AI-based deep learning module for teaching three-dimensional shapes (specifically cube and cuboid) in fifth-grade elementary school. As such, the mathematics content addressed was limited to the topics of element and nets of cube and cuboid for Grade V. Further investigation is needed to determine whether similar instructional modules would be effective in other areas of mathematics, such as number theory, algebra, or statistics. Moreover, the effectiveness of the module in improving students' digital literacy has not been widely tested, as the study involved only 20 students from a single school and was conducted over the course of five meetings. This limited scope restricts the generalizability of the findings; thus, any conclusions should be interpreted with caution. Future research should involve a larger and more diverse sample, as well as an extended duration of implementation to expand upon the current findings.

CONCLUSION

This research produced a mathematics learning design using AI-based deep learning approach in the form of a teaching module on the topics of elements and nets of cube and cuboid for Grade V elementary students. The learning design was validated by experts in learning design, material, and learning evaluation, resulting in a validation score of 3.64, categorized as very valid. The learning design also proved to be practical based on student response questionnaires, with a practicality score of 3.39, categorized as very practical. The learning design was found to be effective based on the results of the Wilcoxon Signed Rank Test comparing students' digital literacy pre-test and post-test scores, the result if the test are Z = -3.051 and Asymp. Sig. (2-tailed) = 0.002, indicating a statistically significant difference in digital literacy before and after the implementation of the learning design. The average digital literacy score of students increased from 29.35 on the pre-test to 32.55 on the post-test. These results demonstrate that the implementation of the learning design had a significant positive impact on students' digital literacy. Furthermore, research findings indicate that students experienced learning that emphasized understanding, application, and reflection through mindful, meaningful, and joyful learning. They acquired meaningful knowledge by relating the content to real-life contexts, engaged mindful learning through reflective activities that helped them recognize learning goals and areas of improvement, and enjoyed joyful learning through engaging classroom activities and the use of tools such as GeoGebra and ChatGPT, both of which provided new and exciting experiences for students in learning mathematics.

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