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The Effectiveness of Deep Learning Approaches in Improving Literacy and Numeracy in Geography Learning

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ABSTRACT

This study aims to implement and test the effectiveness of a Deep Learning approach that integrates literacy and numeracy competencies into Geography learning. The study is motivated by the absence of a standardized and comprehensive Deep Learning teaching module format adaptable to various Geography topics at the secondary school level to strengthen students' literacy and numeracy skills. This research developed teaching modules, student worksheets, and an information technology–based learning media called "Geo Hepi" on climate and weather material at SMAN 12 Semarang. The research method used a pre-experimental design with a one-shot case study model and a quantitative approach. The research subjects were selected through purposive sampling, namely, class XE students. Data were collected using validation questionnaires, participatory observation sheets, and documentation, and analyzed descriptively using percentage techniques and interval criteria. The results showed that students' literacy and numeracy skills were in the good category, with literacy at 89% and numeracy at 87% in the first meeting, and 88% and 83% in the second meeting. These findings indicate that the Deep Learning approach is effective in improving students' literacy and numeracy competencies in Geography learning.

ARTICLE INFORMATION

Keywords:
deep learning, effectiveness, geography, literacy, numeracy

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INTRODUCTION

The implementation of the Merdeka Learning Curriculum in Indonesia marks a significant milestone in improving the quality of national education by providing space for flexibility, innovation, and creativity in the learning process. This curriculum maintains key elements of the previous policy, such as learning outcomes, learning objectives, student profiles, learning models, and evaluation systems, but emphasizes the development of learning activities that are more adaptive, contextual, and relevant to current developments. One of the main challenges in implementing the Merdeka Curriculum is adapting the learning system to technological advances and the diverse needs of students. To address this, the Ministry of Education, Culture, Research, and Technology (Kemendikbudristek), through the Directorate General of Primary and Secondary Education, recommends integrating the *Deep Learning approach*, which focuses on in-depth understanding of concepts, active student engagement, and the development of critical and creative thinking skills.

Historically, the concept of *Deep Learning* is not new in Indonesia; rather, it is a refinement of the active learning paradigm that has been developing since the 1970s. Models such as *Active Student Learning Methods (CBSA)*, *Active, Creative, Effective, and Enjoyable Learning (PAKEM)*, and *Contextual*

Teaching and Learning (CTL) have instilled the principles of engagement and meaningful learning. In vocational education, the *Teaching Factory* previously emphasized hands-on practice as preparation for the world of work. Now, *Deep Learning* expands this focus by strengthening conceptual and procedural links, applying knowledge to new contexts, and utilizing a holistic approach to optimize the learning experience.

Developed countries such as Finland, Japan, Australia, and South Korea have adopted similar principles to build inclusive, transdisciplinary, and well-being-oriented learning systems. The three main principles of *Deep Learning* are *mindful*, *meaningful*, and *joyful learning.* Mindful learning encourages students to be fully present—mentally and emotionally—in the learning process. The application of *mindfulness* has been shown to improve cognitive functions such as working memory, attention, and executive function, which impact learning effectiveness. Meaningful learning emphasizes the connection between new knowledge and prior experience, so that students can understand the relevance of the material to everyday life and build deep conceptual understanding. Joyful learning creates a fun, stress-free learning atmosphere and encourages students' intrinsic motivation to learn enthusiastically.

These three principles form the foundation of a deep, reflective learning experience that motivates students to grow continuously. Furthermore, *Deep Learning* is rooted in the eight dimensions of the Pancasila Student Profile: faith and devotion to God Almighty; global citizenship; critical reasoning; creativity; collaboration; independence; health; and communication. Professional development refers to various training, education, and learning programs designed to enhance a teacher's expertise, knowledge, and skills, to improve student outcomes. As well as changing pedagogical practice, professional development also aims to influence the teacher's beliefs and attitudes that inform and underpin such practice. At the center of any PD initiative is the idea of 'teachers learning, learning how to learn, and transforming their knowledge into practice for the benefit of their students' growth' (Everett, 2024). These dimensions balance academic aspects and social character, relevant to the needs of society and the 21st-century workplace. Therefore, the description of deep learning focuses more on basic human functions in the social sciences than on its use in machine learning, artificial intelligence, and neuroscience (Kovač et al. 2025). However, implementing the Deep Learning approach in the Merdeka Learning Curriculum still faces various obstacles. Although the Ministry has published *the Academic Manuscript "Deep Learning: Towards Quality Education for All"* (Kemendikdasmen, 2025), teachers' freedom to develop learning materials often results in wide variations in implementation across educational units.

Observations at SMAN 12 Semarang indicate that geography teachers have conceptually understood the Deep Learning approach and implemented it through the Merdeka Curriculum, emphasizing in-depth understanding of the material. This implementation is considered capable of improving the quality of geography learning, although the practice still resembles the 2013 Curriculum pattern. Technology integration is carried out through both online and offline learning, but is often hampered by poor internet connectivity. Teachers also have not fully grasped the eight dimensions of the graduate profile, even though they implicitly implement the principles of joyful, mindful, and meaningful learning. The joyful approach involves a personal approach and creates a pleasant classroom atmosphere; mindful learning is implemented by giving students the freedom to understand the material through guidance on key points to encourage active participation, while meaningful learning is implemented by linking geography material to real-world contexts. However, teachers have never designed a teaching module based on the Deep Learning approach due to the lack of official guidelines or outreach from the Ministry. The teaching modules used are still based on the Merdeka Curriculum, with technology support, although Deep Learning elements are implicitly

incorporated. The main obstacle to developing technology-based modules is limited internet access when many students use them simultaneously, although offline use is relatively smooth.

The application of *Deep Learning* in Geography learning is expected to strengthen students' literacy and numeracy competencies. However, observations indicate that students' literacy skills still rely on teacher presentations and textbooks, while numeracy skills are limited to procedural aspects—namely, calculations and the use of formulas without further data analysis. The lack of interest and motivation in learning stems from a lack of innovative learning media that can stimulate literacy and numeracy. This finding aligns with Fitriani et al. (2025), who showed that students' low literacy and numeracy skills are caused by the suboptimal use of digital media in the learning process. Within the *Deep Learning framework*, the use of digital technology is a crucial aspect in supporting meaningful and interactive learning. SMAN 12 Semarang already has various supporting facilities, such as Quizizz, Kahoot, Canva, Google Forms, Google Earth, and digital geography lab tools. This infrastructure offers significant potential in supporting *Deep Learning,* both online and offline.

Several previous studies have examined the implementation of the Merdeka Curriculum and the *Deep Learning approach***.** Heryanti et al. (2023) emphasized the importance of teacher autonomy and active student participation as key to the success of the Merdeka Curriculum. Daga et al. (2022) highlighted the need for intensive teacher training to enable teachers to design student-centered learning strategies. Wiryanto and Anggraini (2021) linked Ki Hajar Dewantara's humanistic values to the principle of freedom to learn, which balances independence and responsibility. Kadir and Latief (2025) demonstrated that integrating *Deep Learning* with literacy and numeracy can improve students' analytical and numerical skills. Nursyifa and Masyithoh (2023) found a positive correlation between literacy and numeracy skills and learning outcomes. International findings also reinforce the relevance of this research: Zeidan et al. (2010) demonstrated that *mindfulness* improves working memory function; Hua et al. (2024) emphasized the importance of students' experiential context for meaningful learning; and Keller et al. (2023) demonstrated that a fun learning environment through *serious games* can stimulate cognitive engagement.

This research aims to: 1) Design and develop Geography teaching modules and student worksheets based on the *Deep Learning approach* which is integrated with literacy and numeracy competencies; Testing the effectiveness of the learning design in improving students' literacy and numeracy skills; and 2) Providing a contextual, adaptive, and practical learning model that can be used as a reference for implementing *Deep Learning* in the Merdeka Curriculum. The novelty of this research lies in the development of a basic format for a Geography teaching module based on a Deep Learning approach that can be applied to all Geography materials at the high school level, integrating literacy and numeracy aspects. This module is designed not only as an adaptive learning tool but also as an alternative model that can serve as a reference for the implementation of the Independent Curriculum. By creating an empirically tested learning design, this research aims to make a real contribution to the transformation of 21st-century education in Indonesia, especially by strengthening meaningful, in-depth, and sustainable Geography learning.

METHOD

The study was conducted at SMA N 12 Semarang, Semarang City, Central Java. The population and sample in this study were all students of SMA N 12 Semarang, Semarang City, Central Java. This research uses a pre-experimental design with a one-shot case study. The one-shot case study model is a research design that involves only the experimental class, carried out without a comparison (control) class and without an initial test (pretest) (Agustianti et al., 2022). The design was chosen because it can provide an initial picture of the results of a treatment using a learning approach under development, namely the deep learning approach. The sampling technique used was purposive

sampling. Purposive sampling is a nonprobability sampling technique in which researchers deliberately select participants based on criteria or characteristics that align with the research objectives (Ahmad & Wilkins, 2025). This study uses this technique because it aims to examine groups with specific characteristics. This study uses samples derived from teacher recommendations, so the sample is a single class studied in depth: X-E, who are currently studying weather and climate material and have the lowest literacy and numeracy levels.

The data collection technique used was interviews with geography teachers at SMA Negeri 12 Semarang. Interviews were conducted to obtain information on needs, problems encountered, and the infrastructure supporting the implementation of the research. The interview questions were divided into five parts. The first part covers understanding the deep learning approach in geography learning, the application of deep learning to improve the quality of teaching and student understanding, the integration of technology with geography learning based on the deep learning approach, and an understanding of the 8 dimensions of graduate profiles in geography learning with a deep learning approach. Part two covers the application of deep learning, including joyful, mindful, and meaningful approaches in geography learning, and strategies/methods that are fun, meaningful, and conscious for students. The third part covers the design of technology-based teaching modules with a deep learning approach, the factors that support the application of deep learning in teaching modules, and the obstacles to the development or use of deep learning-based teaching modules. The fourth part covers the use of the deep learning approach in improving geography literacy and numeracy skills. The fifth part covers the potential of technological devices for deep learning-based geography learning and the existing technological infrastructure at SMA Negeri 12 Semarang.

A closed questionnaire to assess the validation of deep learning-based learning devices integrated with literacy and numeracy skills in the form of teaching modules and student worksheetss that are designed to be suitable for use in the learning process. The learning device validation questionnaire uses the basis for making this teaching module validation adjusted to the basis for the indicators for making teacher performance instruments based on the Performance Test Assessment (UKIN) of the Ministry of Education and Culture (Kemdikbud) Teacher Professional Education (PPG) made by the PPG Management Team of Al Washliyah Muslim University Medan 2023 (Zulfitri et al., 2023). This indicator consists of 8 objective indicators/CP indicators, 8 Learning Step indicators, and 3 Assessment Indicators, and has been developed into an instrument with provisions for the assessment indicators.

Table 1. Teaching Module Eligibility Criteria

Eligibility Criteria (%)	Interpretation
77,51 - 100	Very Good
55,01 – 77,5	Good
32,51 – 55	Little
10 – 32,5	Very Little

Participant observation sheets to assess the implementation of learning and determine students' literacy and numeracy competencies. The creation of literacy instruments uses indicators in accordance with the National Literacy Movement Assessment and Evaluation Guidelines from the Ministry of Education and Culture in 2017 (Kemendikbud, 2017), so that the indicators used are: 1). Ability to Understand text, which measures the extent to which individuals can understand the contents of the text read, including the ability to identify main ideas, important details, and conclusions, 2). Ability to Compose text, which assesses an individual's ability to write or compose text with a clear, cohesive structure, and in accordance with language rules, 3). Critical Thinking Skills, which measures an individual's ability to analyze, evaluate, and reflect on information obtained from

various sources, 4). Ability to Use Digital Information, which assesses the extent to which individuals can search, filter, and manage digital information effectively and ethically. The creation of numeracy instruments uses numeracy skills indicators as defined by the documentation is used to understand and clarify the research process. Documentation involves implementing literacy and numeracy group discussions.

Table 2. Student Numeracy Literacy Assessment Criteria

Assessment Score (%)	Interpretation
77,51 - 100	Good
55,01 – 77,5	Less Good
32,51 – 55	Not Good

The data analysis technique used was a percentage description formula with statistically determined interval criteria to assess and conclude on the validation quality of learning devices and students' literacy and numeracy skills, which served as a basis for determining the effectiveness of learning using the Deep Learning approach. The percentages obtained were then interpreted using statistically determined interval classes. The classification of validation quality for learning devices included very good, good, less, and very less, as shown in Table 1. The classification of students' numeracy literacy skills was good, less good, and not good, as shown in Table 2.

RESULTS AND DISCUSSION

The initial stage of the research focused on developing Deep Learning tools, including teaching modules, atmospheric materials, student worksheets, assessment instruments, and learning media in the form of PowerPoint presentations and the interactive GeoHepi website. All tools were designed to stimulate students' literacy and numeracy skills through meaningful, reflective, and contextual learning activities. Literacy assessment instruments were compiled based on the National Literacy Movement Assessment and Evaluation Guidelines (Kemendikbud, 2017) with four main indicators: 1) the ability to understand text; 2) the ability to compose text; 3) the ability to think critically, and 4) the ability to use digital information.

Meanwhile, the numeracy skill indicators refer to (Kemendikbud, 2017), which consist of: 1) understanding number concepts; 2) solving mathematical problems; 3) interpreting data and information; 4) mathematical reasoning, and 5) applying numeracy in real contexts. The tool was validated by two expert geography teachers in Semarang City. The validated aspects included content suitability, language, presentation, and compliance with *Deep Learning principles*. The validation summary results are shown in Table 3.

Table 3. Teaching Module Validation Results

Validator	Value Earned	Total Score	Percentage (%)	Category
Validator 1	177	190	93	Very good
Validator 2	170	190	89	Very good
Average	—	—	91	Very good

The average validation score of 91% falls within the very good range of 77.51–100%. This means the Deep Learning-based teaching module is suitable for use in Geography learning to improve students' literacy and numeracy skills. Minor revisions suggested by the validator include improving the writing style, adjusting symbols in the Schmidt–Ferguson climate classification table, and

strengthening the diagnostic assessment. The implementation phase was carried out on 15 and 22 May 2025 in two meetings, each discussing *weather and climate material* as well as *practicum measurements of atmospheric elements* (temperature, rainfall, humidity, air pressure, and wind speed). The geography teacher acts as the main teacher and research collaborator. Observation activities were conducted by two external assessors, who evaluated the learning process and students' literacy and numeracy skills. Observation results showed an increase in students' literacy skills, with average scores of 89% (meeting 1) and 88% (meeting 2), both in the *good category*. Details are shown in Table 4.

Table 4. Summary of Literacy Assessment Meeting 1

Indicator	Mark (%)	Category
Understanding the text	96	Good
Composing text	97	Good
Critical thinking	92	Good
Using digital information	89	Good
Average	89	Good

Qualitative analysis showed that literacy skills improved through group discussions based on a case study of Global Warming. This activity required students to understand the text of the phenomenon, develop scientific arguments, and link information to digital sources through *GeoHepi*. This process aligns with Nurfadhillah et al. (2021) and Devi and Rusdinal (2023), who confirmed that digital media integration can strengthen information literacy and increase learning motivation. The results of the numeracy assessment showed average achievement of 87% (meeting 1) and 83% (meeting 2), both of which were in the good category (Table 5).

Table 5. Recap of Numeracy Assessment Meeting 2

Indicator	Mark (%)	Category
Understanding the concept of numbers	82	Good
Math problem solving	84	Good
Interpretation of data and information	88	Good
Mathematical reasoning	86	Good
Numeracy in a real context	78	Good
Average	83	Good

These findings demonstrate that the Deep Learning approach is effective in strengthening students' numerical and scientific reasoning skills, particularly through field practice. Students calculated the average temperature, air pressure, relative humidity, and the Schmidt–Ferguson climate classification, then interpreted the results in context. These results align with Getenet (2026) and Asmara et al. (2025), who emphasize that numeracy in science is effective when contextualized with real-world phenomena.

The developed teaching module has integrated the principles of meaningful, mindful, and joyful learning as outlined in *the Deep Learning Framework* (Ministry of Education and Culture, 2024). Deep learning-based teaching modules have touched on eight dimensions of graduate profiles, including: 1) faith and devotion to God Almighty; 2) citizenship; 3) critical thinking; 4) creativity; 5) collaboration; 6) independence; 7) health, and 8) communication. Finally, deep learning-based teaching modules have been developed and integrated into a deep learning framework that includes a learning framework, learning experiences, learning principles, and graduate profile dimensions, ensuring that the modules cover all of these aspects. Meaningful learning is achieved through discussion activities

on atmospheric phenomena relevant to students' daily lives. Mindful learning occurs when students are aware of their thought processes as they interpret meteorological data and connect calculation results to field conditions. Joyful learning is evident when students are enthusiastic about using practical tools (barometers, anemometers, thermometers, etc.) outside the classroom, making learning active and enjoyable. This approach effectively creates a holistic, contextual learning experience. The results of this study are consistent with the views of (du Plooy et al., 2024) and (Hava, 2021), who assert that active student engagement in experiential learning can improve motivation, concept retention, and critical thinking.

Deep Learning Approaches encourages students not only to understand texts but also to process information, construct logical arguments, and relate them to geospheric phenomena. Emerging literacy aspects include understanding text meaning, constructing scientific narratives, and utilizing digital information. Group discussions on Global Warming strengthen critical and collaborative thinking skills, as Epik et al. (2025) and Widyaningrum et al. (2025) suggest that problem-based literacy activities enhance students' reflection and conceptual understanding. Collaboration is an essential competency in implementing deep learning approaches (Rahmasyah et al., 2025), as it enhances positive interactions among students, improves conceptual understanding (Li et al., 2025), and increases students' enthusiasm for collaborative learning activities (Yang et al., 2024). The use of Problem-Based Learning (PBL) and Project-Based Learning (PJBL) models has been shown to improve students' literacy skills. This is supported by previous studies, which report that both instructional models significantly enhance learners' reading, writing, and critical literacy abilities (Angraini et al., 2025; Duke et al., 2020)

Another advantage is that integrating *GeoHepi* as a digital medium accelerates access to information and increases students' interest in digital literacy. This is reinforced by the fact that the use of IT-based media can improve writing performance and higher-level thinking, which are part of digital literacy (Bal & Öztürk, 2025; Wang & Fan, 2025). However, challenges arise from time constraints and varying literacy levels among students, necessitating a differentiated learning strategy. Based on this, deep learning-based geography learning can create contextual, critical, collaborative, and problem-solving-oriented learning through the application of Problem-Based Learning. This model encourages student activity, improves literacy skills, and strengthens critical and analytical thinking skills through group discussions.

Numeracy activities demonstrate that students are not only able to calculate but also interpret data and relate the results to real-world geographic contexts. This aligns with the concept of numerical literacy in science by Ilma et al. (2023) and Lestari et al. (2024), which emphasizes the relationship between mathematical reasoning and natural phenomena. The application of *Deep Learning* enables students to achieve three domains of thinking: Cognitive (analysis and synthesis of quantitative data), Affective (high learning motivation and curiosity), and Psychomotor (independent and accurate use of meteorological tools). The use of PBL and PJBL learning models plays an important role in improving numeracy skills (Pratidina et al., 2024; Rehman et al., 2023; Zhang & Ma, 2023). Although the results were excellent, minor challenges were identified, such as differences in numerical ability among students and limited time for practical work. However, overall, observations indicate that this approach effectively develops higher-order thinking skills through data-driven geography learning and real-world contexts. Numeracy does not stop at calculation but develops into data interpretation, phenomenon analysis, and evidence-based decision-making, especially in the context of geography and science. This confirms that numeracy activities in geography learning, combined with a deep learning approach, not only support the achievement of learning objectives but also shape the 8 dimensions of graduate profiles: adaptive, reflective, and able to face the challenges of the times.

The results of this study confirm that the Deep Learning Approaches module integrated with literacy and numeracy: 1) Is suitable in terms of validity and practicality; 2) Effectively improves students' critical, analytical, and reflective thinking skills; 3) Able to integrate *learning by doing* and *learning with understanding*; 4) Encourages the formation of a Pancasila student profile with dimensions of critical, creative, collaborative, and faithful reasoning. Thus, this learning model has the potential to serve as a basic framework for developing Geography teaching modules in high schools aligned with the *Independent Learning paradigm* and the demands *of Society 5.0*.

CONCLUSION

This study demonstrates that the geography teaching module, based on the Deep Learning approach and integrated with literacy and numeracy skills, is feasible and effective for learning at SMA Negeri 12 Semarang. The results of the learning device validation show an average of 91%, placing it in the very good category, indicating that the module meets the standards for content feasibility, language, and pedagogical suitability. The implementation of the learning resulted in increases in students' literacy skills (88–89%) and numeracy (83–87%), both of which are in the *good category*. The principles of *Deep Learning* have been proven to create a contextual, reflective, and enjoyable learning process that encourages active involvement, critical thinking, and students' problem-solving abilities regarding geospheric phenomena. Geography teachers are advised to adopt this *Deep Learning teaching module* as an alternative learning method that integrates literacy, numeracy, and spatial context. Further research is needed using a quasi-experimental design, a longer timeframe, and a larger sample size to test its comparative effectiveness and assess its long-term impact on students' higher-order thinking skills.

DECLARATION OF GENERATIVE AI

The authors declare that no generative AI or AI-assisted technologies were used in the writing process of this manuscript.

CONFLICTING INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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