PROFESI PENDIDIKAN DASAR
Volume 13, Issue 2, August 2026, pp. 137-157
p-ISSN: 2406-8012, e-ISSN: 2503-3530
https://journals2.ums.ac.id/index.php/ppd

Impact of 6C Integrated Deep Learning on Pre-service Elementary Teachers' Social Studies Understanding

Repita Purnama Sari[1*], Safitri Yosita Ratri[1], Banu Setyo Adi[1], Efi Tri Astuti[2], Fery Muhammad Firdaus[1], Hendra Setyawan[1], Suliat Adeola Ojetunde[3]
[1]Yogyakarta State University, Indonesia
[2]Sunan Kalijaga State Islamic University, Indonesia
[3]University of Hull, United Kingdom
*Corresponding Author's Email: *repitapurnama.2025@student.uny.ac.id*

How to cite: Sari, R. P., Ratri, S. Y., Adi, B. S., Astuti, E. T., Firdaus, F. M., Setyawan, H., & Ojetunde, S. A. (2026). Impact of 6C Integrated Deep Learning on Pre-service Elementary Teachers' Social Studies Understanding. *Profesi Pendidikan Dasar*, *13*(2), 137–157. https://doi.org/10.23917/ppd.v13i2.18150

Keywords:
6C skills; deep learning; pre-service elementary teachers; understanding of basic concepts; social studies

Article History:
Submitted: 2026-06-09
Revised: 2026-07-26
Accepted: 2026-08-21

Abstract

Digital education transformation requires pre-service elementary teachers to possess solid pedagogical foundations and deep conceptual mastery. This study evaluated the effectiveness of a 6C-integrated Deep Learning model in enhancing pre-service elementary teachers' understanding of the Basic Concepts of Social Studies. Using a quantitative quasi-experimental, single-group time-series design, 39 pre-service elementary teachers (N=39) were assessed through repeated conceptual understanding tests and Student Worksheets for Learning (LKM) applying meaningful, mindful, and joyful principles. Data were analysed using Repeated Measures ANOVA, supplemented by Rasch model calibration, descriptive statistics, and Spearman's rank correlation. The 6C-integrated Deep Learning model significantly improved students' conceptual understanding ($F = 23.930$; $p < .001$), with empirical LKM data confirming this trend through an average score increase from 65.26 to 91.85. Critical Thinking emerged as the highest-scoring 6C indicator on the Likert scale ($M = 3.17$). These findings suggest that integrating Deep Learning with the 6C framework can enhance pre-service elementary teachers' conceptual understanding, promote higher-order learning competencies, and support teacher education through more reflective and adaptive learning experiences.

INTRODUCTION

Background of the Study

Educational transformation in Indonesia through the implementation of the Merdeka Curriculum requires teachers to move beyond conventional teacher-centered instruction toward a more flexible pedagogical paradigm (Hunaepi & Suharta, 2024), while rapid school digitization demands a balance between technological adoption and teachers' pedagogical readiness. Although the government continues to promote school digitization, teachers' mental and pedagogical readiness remains a major challenge in achieving national literacy targets amid rapid technological development (Timotheou et al., 2023; Mhlongo et al., 2023), while their preparedness for the Artificial Intelligence era is strongly influenced by their mental resilience (Muttaqin, 2022). These conditions contribute to persistent difficulties among elementary school (SD/MI) teachers in designing authentic assessments that support the Deep Learning model (Asitah et al., 2026), leading some teachers to prioritize administrative compliance over meaningful improvements in instructional quality (Rivera et al., 2025). However, the success of the Merdeka Curriculum depends heavily on teachers' ability to adapt learning materials to students' needs and local contexts (Nurhidayani et al., 2025), while insufficient ongoing support, particularly in rural areas, contributes to continued curriculum misinterpretation (Lin et al., 2025). Limited opportunities for professional reflection further hinder teachers' understanding of the curriculum's essence (Putri & Fitria, 2023). Ultimately, these challenges are closely related to the preparation of pre-service elementary teachers, as teacher readiness depends partly on how well prospective PGMI teachers develop foundational knowledge during their undergraduate studies, including courses such as "Basic Concepts of Social Studies for MI/Elementary School", which are still often taught through rote memorization.

To address this gap, current changes in education policy require higher education institutions to reform their teaching models. Education in Indonesia is now entering a new phase, marked by the formal adoption of the Merdeka Curriculum as the National Curriculum in March 2024, which serves as the primary guide for teachers designing curricula at the school level (Kemendikbudristek, 2022). This phase represents a refinement of the post-COVID-19 transition period, during which the Deep Learning approach has been extensively incorporated to maintain relevance and address future educational challenges (Qomariyah & Maghfiroh, 2022). Overcoming low conceptual understanding requires a comprehensive model that integrates the 6C competencies. According to Fullan (2025), internalization of the 6C competencies is a primary determinant of pre-service elementary teachers' self-efficacy. The Character and Citizenship dimensions serve as the ethical foundation for constructing contextual learning values. Pre-service elementary teachers must draw on Critical Thinking to reflect deeply on the dynamics of curriculum change, while Creativity is necessary to harness artificial intelligence technology as an innovative pedagogical tool. Mastery of Collaboration and Communication, in turn, fosters collective agency within the academic ecosystem. Together, these competencies help bridge the gap between ideal theory and instructional reality in elementary schools. Without holistic integration of the 6Cs, pre-service elementary teachers risk experiencing pedagogical dissonance and reverting to conventional methods. By internalizing these principles, pre-service elementary teachers can transition from passive knowledge transmitters into learning architects who build deep connections between the curriculum and the real world (El-aasar et al., 2024).

Evaluating the impact of training models on teacher practices is particularly important during this policy transition period, as the implementation of the National Curriculum offers a crucial opportunity to assess the extent to which teachers' critical reflection can sustain educational innovation (Shen et al., 2025). The 2024 policy evaluation conducted by the Ministry of Education, Culture, Research, and Technology provides a vital foundation for ensuring that this transition amounts to more than an administrative change, supporting a genuine restoration of learning quality (Ariga, 2023). Beyond reflective skills, the evolution of global education in today's digital age requires teacher-training institutions to produce pre-service elementary teachers with an adaptive mindset toward the growing presence of artificial intelligence (Padua, 2025). This adaptability depends heavily on self-efficacy, a key predictor of successful adaptation to dynamic environments (Hu & Cai, 2026) that also significantly shapes the academic achievement and learning motivation of the students they will eventually teach (Cheng et al., 2026). Furthermore, the Merdeka Curriculum, which promotes mindful, meaningful, and joyful learning, will only be effective if pre-service elementary teachers are confident in translating these principles into real classroom practice (Chotimah & Fantofik, 2025), a confidence that is heavily shaped by systemic support within the school environment (Li et al., 2025). Addressing prospective educators' unpreparedness for dynamic curriculum change is therefore essential to preventing learning failures and fostering a quality learning ecosystem through strengthened literacy and self-efficacy (Law et al., 2025). While prior literature has extensively discussed the general concept of Deep Learning, the novelty of this study lies in providing empirical evidence on the specific process of integrating the 6C framework into Social Studies teacher preparation, equipping pre-service teachers with a solid grasp of 21st-century pedagogy (Mir, 2025).

Problem of the Study

On an international scale, implementing deep learning approaches through adaptive artificial intelligence systems in Finland has been shown to boost academic achievement by 25% and elevate student engagement by up to 30% (Hadevi et al., 2026). Concurrently, Singapore's integration of inquiry-based models within deep learning frameworks has reinforced 21st-century skill mastery by fostering active student participation (Kenaphoom, 2024). Conversely, the adoption of this methodology in Vietnam has challenged educators to adapt to new roles as facilitators and sources of emotional support amid rapid technological integration (Nguyen et al., 2025). Teachers in China have likewise encountered significant barriers to cultivating higher-order cognition in virtual classrooms due to constrained pedagogical interactions and limited instructional strategies (Jiang, 2022). Collectively, while this strategy can optimize learning outcomes by up to 91.9%, managing excessive workloads remains a critical constraint for educators operating within virtual learning environments (Mohammad Zadeh & Ferrari, 2026). Therefore, these global variations highlight that the success of deep learning integration depends heavily on mitigating teacher burnout and enhancing pedagogical readiness.

Social Studies education explicitly requires the 6C framework (Character, Citizenship, Collaboration, Communication, Creativity, and Critical Thinking) due to its unique curricular characteristics, which demand rigorous analysis of complex social phenomena and a more intensive internalization of civic values compared to other academic disciplines (Ursula et al., 2025). Within this framework, Social Studies instruction can be transformed into a vehicle for cultivating global competencies, equipping students with social empathy and collaborative problem-solving capabilities in an increasingly complex society (Inganah et al., 2023). Existing literature offers little in-depth exploration of early-semester, student-level interventions, as research has predominantly focused on macro-level policy evaluations and educators' administrative readiness (Apriliantty, 2025). Furthermore, students' cognitive adaptation during initial semester transitions remains understudied, largely due to the absence of explicit quantitative indicators and limited adaptive curricular designs tailored to individual student profiles (Karimulloh et al., 2026). Empirical interventions that synthesize deep pedagogy with adaptive systems remain scarce, as prior studies have predominantly examined conceptual foundations rather than instructional practices beginning from the very first classroom encounter (Warnia et al., 2026). Taken together, integrating the 6C approach through early-semester, student-focused interventions is essential to bridging the gap between curriculum policy and instructional practice in schools.

The Deep Learning approach emerges as a strategic solution to equip pre-service elementary teachers with a thorough and comprehensive understanding of concepts. This strategy guides pre-service elementary teachers to move beyond rote memorization toward holistically connecting information (Biedermann et al., 2025). Through Deep Learning, pre-service elementary teachers are encouraged to explore the relationship between educational theory and real-world classroom challenges (Gao et al., 2025). The integration of this approach has proven effective in enhancing pre-service elementary teachers' critical thinking skills and adaptability to dynamic curriculum changes (Baihaqi et al., 2025). Sustainable educational innovation relies heavily on teachers integrating their training experiences into daily practice (Jimoh, 2025). Mastery of Deep Learning serves as the primary foundation for pre-service elementary teachers to design more meaningful social studies learning strategies. The primary focus of this approach is to help pre-service teachers develop a lasting understanding they can later impart to their own students.

In practice, however, a gap remains relative to these competency standards. Observations among 39 prospective PGMI (Islamic Elementary Education) teachers in Class C, second semester, at Universitas Islam Negeri (UIN) Sunan Kalijaga confirm low levels of the 6C indicators in academic activities. Students tend to be engrossed in virtual activities via their smartphones rather than fostering Communication and Collaboration in the classroom. The lack of engagement in discussions reflects weak Critical Thinking and Creativity. The use of artificial intelligence in group assignments remains largely administrative, lacking substantive deep learning processes within the Character and Citizenship dimensions. Pre-service elementary teachers must nonetheless be equipped with the cognitive skills needed to educate and serve as role models for their future students. The quality of presentations, which often involve merely reading text aloud, indicates weak internalization of foundational social studies concepts for MI/SD (Islamic and public elementary school) levels. This phenomenon demonstrates that without the habit of deep thinking, these pre-service teachers will struggle to convert theory into practice.

Research's State of the Art

Educational transformation through the Merdeka Curriculum demands a paradigm shift from administrative teaching to a deeper pedagogical understanding. Empirical evidence suggests that there is a fundamental tension between technological capabilities and pedagogical readiness in the implementation of the current curriculum. Ali (2025) found that an AI-based management system significantly optimized operational efficiency, achieving an effectiveness score of 84% in the experimental group; however, the integration of such technology does not automatically guarantee substantive learning. This operational success stands in stark contrast to findings from Arina and Isyanto (2025), who found that teachers remain constrained by an administrative mindset that hinders genuine Deep Learning implementation, regardless of digital tool availability. This gap underscores that digital infrastructure serves only as a supporting factor, not the primary driver of educational reform. Therefore, meaningful curriculum transformation requires a harmonious synthesis in which technology actively supports rather than replaces deep pedagogical understanding.

Teachers' limited understanding, at the operational level, of how to bridge abstract concepts with concrete reality is a major obstacle to learning. Efendi et al. (2025) demonstrated, through classroom action research, that a coin-assisted Deep Learning approach increased student learning mastery from 21.4% in the pre-cycle to 89.2% in the second cycle. This success is reinforced by findings from Cahyanto (2025), showing that a Deep Learning model emphasizing mindful and joyful aspects qualitatively strengthens students' reading literacy through the stages of discovering, interpreting, and evaluating information. The ability to convert concrete media into deep learning tools is an urgent necessity for every pre-service educator. Ramadan et al. (2026) found that applying a Problem-Based Learning (PBL) model oriented toward the deep learning principles of mindfulness, meaningfulness, and joy significantly increased the conceptual understanding, contextual reasoning, and affective engagement of fourth-grade elementary school students. Research on Deep Learning has indeed expanded, yet the majority of the literature still focuses on general implementation in elementary schools, leaving a critical need to further examine how teachers' pedagogical competencies can be enhanced in alignment with the 6C framework.

The Deep Learning approach emerges as a strategic solution to equip pre-service elementary teachers with a deep and comprehensive understanding of concepts. Deep Learning is framed as an instructional paradigm that shifts the learning focus from surface-level rote memorization toward constructing profound cognitive connections, critical understanding, and long-term retention through mindful, meaningful, and joyful learning experiences (Zhao et al., 2025). This strategy guides pre-service elementary teachers not merely to memorize material but to connect various pieces of information holistically (Biedermann et al., 2025). Through Deep Learning, pre-service elementary teachers are encouraged to explore the relationship between educational theory and real-world challenges in the classroom (Gao et al., 2025). To operationalize this deep cognitive process, the integration of the 6C competencies plays a pivotal role in Social Studies education. Within this discipline, the 6Cs are defined as an integrative framework of 21st-century learning domains comprising Character (ethical foundation and social responsibility), Citizenship (civic awareness and democratic participation), Critical Thinking (analytical evaluation of social phenomena), Creativity (innovative problem-solving in human contexts), Collaboration (interpersonal synergy in social inquiry), and Communication (articulation of complex socio-cultural ideas) (Bulkis et al., 2025).

Recent empirical evidence specifically addressing Social Studies Fundamentals reinforces the critical role of engagement, teacher capacity, and integrated instructional practices within this discipline. Savitri et al. (2026) demonstrated that student learning activity has a very strong positive correlation with the understanding of basic Social Studies concepts ($r_s = .808$; $p < .001$), while learning motivation shows a moderate significant relationship ($r_s = .396$; $p < .001$) and acts as a strong driver of engagement ($r_s = .637$; $p < .001$). Qualitative findings from Bihag et al. (2025), involving 6 Social Studies teachers, highlighted six core instructional practice themes, ranging from integrated methods and technology enhancement to personalized learning and holistic development, that optimize student skill application. The integration of this approach has proven effective in enhancing pre-service elementary teachers' critical thinking skills and adaptability to dynamic curriculum changes. Sustainable educational innovation heavily relies on teachers integrating their training experiences into daily practice (Jimoh, 2025). Mastery of Deep Learning serves as the primary foundation for pre-service elementary teachers to design more meaningful social studies learning strategies. The primary focus of this approach is to foster in pre-service elementary teachers a lasting understanding they can later impart to their own students. The urgency of selecting the "Basic Concepts of Social Studies" course in this study is based on the characteristics of Social Studies material, which functions as a social laboratory for the development of 21st-century competencies. As a field of study that examines complex human phenomena, Social Studies requires the tangible integration of the 6Cs to transform a collection of social facts into reflective critical understanding through a Deep Learning approach.

Pre-service elementary teachers' readiness to adopt modern pedagogy is not merely a technical issue but is predominantly tied to mastery of 21st-century competencies. Fitrah et al. (2025) found through regression analysis that 21st-century competencies contribute 37.2% to teacher readiness, higher than the technological factor, which only accounts for 11.5%. Training programs emphasizing a Growth Mindset and the Deep Learning framework have been qualitatively proven to enhance teachers' confidence in designing reflective learning experiences (Musfirah et al., 2025). Strengthening higher-order thinking skills at the pre-service teacher level serves as an essential preventive measure against pedagogical unpreparedness. Given this urgency, this study aims to test the effectiveness of integrated 6C Deep Learning to strengthen pedagogical readiness among pre-service teachers in the Basic Concepts of Social Studies course.

Gap Study and Objective

Enhancing pre-service elementary teachers' pedagogical mastery in designing learning experiences is crucial for effective instruction. Widely available technological tools do not fully enhance teaching readiness unless accompanied by higher-order thinking skills (Galimova et al., 2025). Most existing training models remain theoretical and have not holistically addressed the integration of 21st-century skills in developing learning strategies (Tijani & Adeduyigbe, 2026). The research focus, which has largely centered on improving student learning outcomes, has also left a significant gap in the analysis of how pre-service elementary teachers develop their understanding as instructional designers.

Recent literature highlights the multidimensional nature of deep learning and pedagogical readiness in elementary education. Sunarto and Wardhanie (2026) demonstrate that deep learning accelerates cognitive maturation and 6C skills, though it risks inducing cognitive overload without tailored scaffolding. This pedagogical execution strongly relies on teachers' digital readiness and practical training. Hermita et al. (2025) observed that structured STEM-coding interventions significantly improve teachers' ability to construct deep learning lesson plans. Similarly, Dedy et al. (2025) found that applying deep learning framework devices successfully shifts pre-service teachers' paradigms toward 6C-oriented instructional design, despite constraints in time and technology media. Santosa et al. (2025) revealed that self-efficacy ($r = .319$) and digital learning environments ($r = .381$) significantly drive deep learning implementation. Rizkasari et al. (2026) empirically highlight that elementary school teachers demonstrate good conceptual understanding of deep learning (score 3.65 out of 4), yet their classroom enactment (3.40) and school implementation readiness (3.25) remain moderate due to constraints in time, instructional media, and technical training. Nevertheless, Aridan et al. (2024) emphasize that deep learning readiness remains cross-regionally disparate due to demographic and institutional variations. A critical challenge in this context is assessment literacy. Setiyowati et al. (2025) uncovered that while teachers grasp general pedagogical concepts, they consistently struggle to construct evaluative and creative higher-order thinking skills (HOTS) assessments. To address such complex competencies, Dong (2022) underscores the necessity of task-based learning frameworks to strengthen connectivity and real-world 6C skill development.

The literature reveals the critical roles of deep learning frameworks, curriculum understanding, self-efficacy, and 6C integration in shaping pedagogical readiness and instructional design. However, previous studies have largely analysed teacher readiness, digital environments, and assessment literacy as isolated variables. No study has holistically investigated how a structured Deep Learning intervention embedded within the 21st-century 6C framework operates across specific elementary Social Studies (IPS) core topics (human needs, geographical issues, and socio-cultural characteristics). Hence, this study aimed to explore the process of developing pre-service elementary teachers' understanding as instructional designers and to evaluate the effectiveness of a 6C-based Deep Learning approach in improving pre-service teachers' pedagogical mastery and IPS content construction capabilities within the Merdeka Curriculum context.

METHOD

Type and Design

This study employed a quantitative quasi-experimental time-series design, featuring a single experimental group evaluated across six sequential, equidistant measurement phases (O_1 to O_6) to observe performance trends before and after the intervention (Creswell & Creswell, 2023). A single-group time-series design was intentionally selected to balance two competing priorities: the ethical imperative of not withholding a pedagogically superior 6C-integrated Deep Learning intervention from a control cohort, and the need for ecological validity within a highly homogeneous pre-service teacher population. The inclusion of three pre-intervention baseline measurements (O_1, O_2, O_3) helped establish a stable performance baseline and familiarized participants with the evaluation format, partially mitigating threats related to maturation, history, and testing effects. Any statistically significant trend inflection or level shift observed across the post-intervention phases (O_4, O_5, O_6) was therefore taken as evidence that gains in pre-service elementary teachers' IPS instructional design mastery are attributable to the 6C Deep Learning model rather than to external confounding variables or random fluctuation.

Nonetheless, because this single-group design lacked a control group, it could not fully eliminate threats to internal validity such as maturation and historical effects. Repeated administration of evaluation tasks across six measurement phases also created a potential testing effect, whereby score improvements may have partly reflected participants' growing familiarity with item structures rather than genuine learning gains. To mitigate this risk, test items across equivalent evaluation sets were item-banked and their sequencing rotated across administrations, with a mandatory one-week interval maintained between treatment cycles to reduce recall-based bias.

Data and Data Sources

This study was conducted among a population of all second-semester pre-service teachers enrolled in the "Basic Concepts of Social Studies for Elementary School (MI/SD)" course within the Madrasah Ibtidaiyah Teacher Education Program (PGMI) at UIN Sunan Kalijaga State Islamic University, Yogyakarta, during the 2025/2026 academic year (N = 125). A sample of 39 pre-service teachers from Class C was selected using purposive sampling based on their enrolment in the course during the implementation of the 6C-integrated Deep Learning intervention and their fulfilment of predetermined inclusion criteria. Participants had a mean age of 19.2 ± .6 years, were predominantly female (84.6%, n = 33; male 15.4%, n = 6), and held a mean prior cumulative GPA of 3.58 ± .21. Baseline evaluations indicated that participants possessed uniform, lower-level prior Social Studies (IPS) content knowledge, heavily constrained to theoretical reading and rote memorization during presentations, with zero prior exposure to structured Deep Learning frameworks or 6C-based pedagogical strategies. Furthermore, their initial engagement with artificial intelligence tools was purely administrative and lacked cognitive synthesis, ensuring high institutional homogeneity and identical cognitive entry behavior across the cohort.

The data collected comprised two complementary quantitative data sets alongside attitudinal metrics. The first data set consisted of multiple-choice test (MCT) scores, measuring pre-service teachers' cognitive domain and conceptual understanding of Social Studies instruction across the six sequential measurement phases (O_1 to O_6). The second data set comprised scores from Student Learning Worksheets (LKM), empirically evaluating their concrete performance and practical ability to construct IPS learning strategies. These datasets were further supplemented by a 4-point Likert scale measuring pre-service teachers' perceptions and self-efficacy across the 6C framework variables and indicators. Selecting second-semester students at this early developmental stage provided strategic empirical insights, as enhancing their instructional design capabilities directly impacts their long-term professional pedagogical mastery.

Data Collection Technique

Data collection was systematically executed over a total research period of six weeks, encompassing three instructional sessions each lasting 100 minutes (equivalent to two credit hours at 50 minutes per credit hour), with a one-week observation interval between sessions. The measurement timeline was structured around paired pretests and posttests (O_1 to O_6) administered across three treatment cycles. To ensure rigorous construct validity, the research instruments were developed based on a structured operational matrix aligning Social Studies content standards with Bloom's revised taxonomy for higher-order cognitive levels and Fullan's 6C competency framework. Content validity was systematically verified through expert judgment by senior Social Studies education lecturers prior to empirical field testing. Specifically, O_1, O_3, and O_5 were administered as pretests at the beginning of Sessions 1, 2, and 3, respectively, to establish baseline knowledge prior to each topic. The 6C-integrated Deep Learning intervention was implemented during each 100-minute instructional session, followed immediately by posttests O_2, O_4, and O_6 at weekly intervals to capture progressive cognitive gains and instructional strategy mastery.

Before the treatment phase began, the researcher conducted validity and reliability tests of the instrument using the Rasch Model via MINISTEP (version 5.8.3.0) and SPSS, on 30 second-semester pre-service teachers meeting the same criteria at Muhammadiyah University of Oku Timur. Validity and reliability tests for multiple-choice questions were conducted using SPSS, which provides Pearson correlation and Cronbach's Alpha analyses for testing the internal consistency of dichotomous data in the learning achievement test instrument. The validity results were obtained from the "Item (Column) Fit Order" output table; the quality of each test item was assessed using the criteria Outfit MNSQ, Outfit ZSTD, and PT Measure Corr (Sumintono & Widhiarso, 2014). Table 1 shows the research design framework.

Table 1. Research Design Framework

Pretest	Treatment	Posttest
O1	X	O2
O3	X	O4
O5	X	O6
LKM and Likert Scale (1–4) served as supplementary empirical evidence collected alongside this design		

To comprehensively measure pre-service teachers' pedagogical and content capabilities, three distinct research instruments were deployed, each serving a specific evaluation purpose. The Multiple-Choice Achievement Test (MCT) / Evaluation Tests 1, 2, and 3 quantitatively measured pre-service teachers' cognitive domain and conceptual understanding across three core Social Studies (IPS) topics: Types of Human Needs (Evaluation 1), Population Concepts and Geographical Issues (Evaluation 2), and Environmental and Sociocultural Dynamics (Evaluation 3). Test items were analysed using SPSS software, applying classical test theory parameter estimation, point-biserial correlation, and internal consistency analysis. An item was deemed valid if $p < .05$ (Sig. 2-tailed) and reliable if Cronbach's alpha $> .6$. Tested on 30 second-semester PGSD (Elementary School Teacher Education) pre-service teachers at Muhammadiyah University of East OKU across a 30-item test: Evaluation 1 yielded 24 valid and 6 invalid items ($\alpha = .733$), Evaluation 2 yielded 27 valid and 3 invalid items ($\alpha = .778$), and Evaluation 3 yielded 26 valid and 4 invalid items ($\alpha = .756$), all falling into the high reliability category.

Table 2. Validity and Reliability Testing of the Evaluation Tests

Evaluating Test	Social Studies (IPS)	Valid Items	Invalid Items	Cronbach Alpha (α)	Reliability Category
1	Types of Human Needs	24	6	.733	High
2	Population Concepts and Geographical Issues	27	3	.778	High
3	Environmental and Sociocultural Dynamics	26	4	.756	High

Student Learning Worksheets (LKM 1, 2, and 3) were employed to empirically evaluate pre-service teachers' practical, performance-based capabilities in collaborative small groups when constructing 6C-aligned IPS instructional strategies. Three distinct LKM modules were developed corresponding to the three core IPS topics. The evaluation rubrics for LKM 1, LKM 2, and LKM 3 were validated through expert judgment by senior IPS education lecturers, ensuring content appropriateness and construct alignment. Field trial results from 30 second-semester PGSD pre-service teachers at Muhammadiyah University of East OKU demonstrated strong empirical validity ($p < .05$) and high internal consistency reliability ($\alpha > .60$) across all performance rubric dimensions. Out of 26 total rubric indicators evaluated across the three worksheets, 25 indicators were declared valid and 1 indicator was declared invalid (dropped). Specifically, LKM 1 yielded 8 valid items and 0 invalid items ($\alpha = .812$), LKM 2 yielded 9 valid items and 1 invalid item ($\alpha = .785$), and LKM 3 yielded 8 valid items and 0 invalid items ($\alpha = .834$).

Table 3. Validity and Reliability Testing of the LKM Rubric Indicators

Evaluating Test	Social Studies (IPS)	Valid Indicators	Invalid Indicator	Cronbach Alpha (α)	Reliability Category
1	Types of Human Needs	8	0	.812	Very High
2	Population Concepts and Geographical Issues	9	1	.785	High
3	Environmental and Sociocultural Dynamics	8	0	.834	Very High

A 6C Attitudinal Questionnaire, comprising two variables (X and Y), was used to evaluate pre-service teachers' self-efficacy, perceptions, and attitudinal tendencies toward the 6C-integrated Deep Learning approach. Prior to the treatment phase, validity and reliability tests were conducted on 30 second-semester pre-service teachers at Muhammadiyah University of East OKU who met the study criteria. The psychometric evaluation was analysed using the Rasch Model via MINISTEP (version 5.8.3.0), as it converts ordinal Likert data into linear interval logit measures and provides item-person fit criteria (Outfit MNSQ, Outfit ZSTD, and PT Measure Corr) from the Item Fit Order output (Sumintono & Widhiarso, 2014). Out of 20 questionnaire items tested, 18 items were deemed valid, while 2 items were dropped due to misfitting. The person reliability coefficient was .82 and item reliability was .88, demonstrating high instrument consistency. Meanwhile, the multiple-choice achievement tests (MCT) were analysed using SPSS to perform Pearson correlation and Cronbach's Alpha analyses. Tables 4 and 5 show the two variables: X (6C-integrated Deep Learning) and Y (pre-service elementary teachers' understanding of basic Social Studies concepts).

Table 4. Item Fit Statistics for Variable X (6C-Integrated Deep Learning)

Number Questions	MNSQ Score	ZSTD Score	PT Measure Corr Score	Conclusion
X1	.36	-1,64	.83	Relevant
X2	.76	-.36	.51	Highly Relevant
X3	.80	-3,30	.68	Relevant
X4	1,52	1,17	.63	Relevant
X5	.97	.11	.74	Partially Relevant
X6	.80	-.35	.80	Highly Relevant
X7	.61	-.76	.85	Highly Relevant
X8	.39	-1,45	.62	Relevant
X9	1,05	.26	.61	Highly Relevant
X10	.99	-.16	.67	Highly Relevant
X11	.69	-.55	.58	Highly Relevant
X12	.99	.15	.75	Highly Relevant

Table 5. Item Fit Statistics for Variable Y (Understanding of Basic Social Studies Concepts)

Number Questions	MNSQ Score	ZSTD Score	PT Measure Corr Score	Conclusion
Y1	.87	-.12	.57	Highly Relevant
Y2	.51	-1,09	.78	Highly Relevant
Y3	1,02	.20	.44	Highly Relevant
Y4	.79	-.47	-.33	Relevant
Y5	.82	-.24	.65	Highly Relevant
Y6	.80	-.28	.57	Highly Relevant
Y7	1,46	1,03	.74	Highly Relevant
Y8	1,22	.62	.61	Highly Relevant
Y9	.64	-.69	.73	Highly Relevant
Y10	1,36	.89	.52	Highly Relevant
Y11	.75	-.42	.63	Highly Relevant
Y12	.62	-.81	.75	Highly Relevant
Y13	.89	-.08	.75	Highly Relevant
Y14	.99	.14	.74	Highly Relevant

Data Analysis

This technique was chosen because the respondents had specific characteristics, namely pre-service elementary teachers currently taking the course "Basic Concepts of Social Studies for Elementary School." The Rasch Model was selected for use with the Likert scale because it can convert ordinal data into more precise interval (logit) data and can simultaneously detect interactions between respondents' ability levels and item difficulty levels through the fit statistics criteria in Table 6.

Table 6. Rasch Model Criteria (Sumintono & Widhiarso, 2014)

Outfit	Criteria
MNSQ	.5 < x < 1.5
ZSTD	2.0 < x < +2.0
PT Measure Corr	.4 < x < .85

After the test data were collected, the researcher administered pretests and posttests to the students, analysed using a repeated-measures ANOVA in JASP to determine whether there were significant differences between pretest and posttest results. These findings were further supported by empirical evidence from the LKM and a four-point Likert scale. This four-point Likert scale did not include a neutral option, to avoid data ambiguity. Data obtained from the Likert scale and the LKM were analysed using descriptive statistics to strengthen the quantitative findings. The interval criteria and interpretation of the LKM's effectiveness are presented in Tables 7 and 8 as follows.

Table 7. Interval Scale

Value	Description
Very Low	1.00 – 1.75
Low	1.76 – 2.50
High	2.51 – 3.25
Very High	3.26 – 4.00

Table 8. Interpretation of Effectiveness Scores (Wahab et al., 2021)

Succes Rate	Meaning
0% - 20%	Very Ineffective
21% - 40%	Ineffective
41% - 60%	Moderately Effective
61% - 80 %	Effective
81% - 100%	Very Effective

To further examine the comprehensive efficacy of the model, a bivariate correlation analysis was also incorporated. A multivariate normality prerequisite test was initially conducted using the Shapiro-Wilk check. Since the results indicated that the data from the Deep Learning psychological scale were not normally distributed ($p < .05$), the analysis proceeded using the non-parametric Spearman's Rank Correlation Matrix. This statistical test was specifically deployed to map the interactive dynamics and continuous developmental stability between initial understanding, final understanding, and students' subjective psychological tendencies. This analysis aimed to examine the trends in pre-service elementary teachers' responses to the implementation of the social studies learning strategies they developed. By triangulating the results, researchers were able to draw comprehensive conclusions regarding the success of the experiment and the factors influencing pre-service elementary teachers' ability to apply reflective learning strategies.

RESULTS

This study aimed to examine pre-service elementary teachers' understanding of 6C-integrated Deep Learning. Data were collected through a series of multiple-choice tests (MCT) with identical questions used as pretests and posttests to assess the extent of the intervention's impact. The results of the descriptive analysis are presented in Table 9. Results of the descriptive analysis of 39 PGMI pre-service teachers indicate a consistent trend of increased understanding in the Basic Concepts of Social Studies course at each stage of the intervention. This is evidenced by a gradual increase in the mean score, starting from Pretest 1 (M = 65.26) and reaching its peak at Posttest 3 (M = 91.85). The data distribution at each level was stable, with a low standard deviation at every stage. Overall, the increase in scores from the initial pretest to the final posttest suggests that the implementation of the 6C-integrated Deep Learning model is effective in improving students' understanding in a gradual and consistent manner.

Table 9. Descriptive Statistical Analysis

RM Factor 1	N	Mean	SD	SE	Coefficient of variation
Pre-test 1	39	65.26	3.290	.527	.050
Pre-test 2	39	69.18	3.331	.533	.048
Pre-test 3	39	73.15	3.360	.538	.046
Post-test 4	39	79.74	3.768	.603	.047
Post-test 5	39	86.13	3.526	.565	.041
Post-test 6	39	91.85	3.667	.587	.040

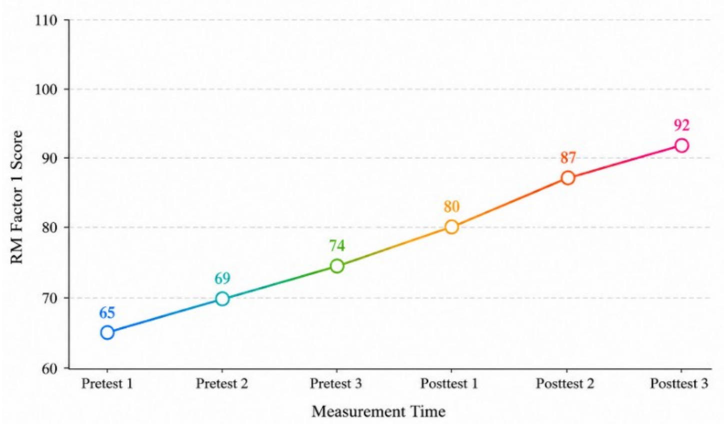

Figure 1. Trend Graph of the Increase in Average Student Comprehension Scores

The plot in Figure 1 shows a clear upward trend in student comprehension from Pretest 1 to Posttest 3. The short error bars at each point indicate that the data distribution is highly consistent and precise, supporting the effectiveness of the 6C-integrated Deep Learning model in gradually improving students' understanding at each phase.

Table 10. Test of Assumptions

Test of Sphericity

	Mauchly's W	Approx. X^2	df	p-value	Greenhouse-Geisser ε	Huynh-Feldt ε	Lower Bound ε
RM Factor 1	.041	115.1	14	< .001	.436	.463	.200

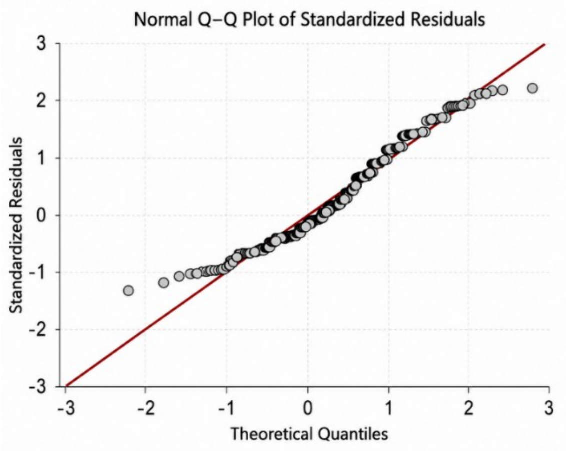

Figure 2. Q-Q Plot of Assumption Test

Table 11. Repeated Measures ANOVA Results

Cases	Sum of Squares	df	Mean Square	F	p
RM Factor 1	20410[a]	5[a]	4082[a]	23930[a]	< .001[a]
Residuals	32.41	190	.171		

Based on the assumption test in Table 10, the sphericity assumption was not met (Mauchly's W = .041; p < .001). Therefore, a correction was applied using the Greenhouse-Geisser method (ε = .436) to maintain the accuracy of the ANOVA results. Based on Figure 2, the data points closely follow the diagonal line. This visually indicates that the students' comprehension data are normally distributed, thus fulfilling the normality assumption for the Repeated Measures ANOVA test. Based on the results of the Repeated Measures ANOVA test in Table 7, a highly significant effect of the application of the 6C integrated Deep Learning model on students' understanding was found: F = (5.190) = 23,930 with a significance level of p < .001. A significance value of less than .001 indicates that there is a real and consistent difference in understanding among the six measurement levels.

Table 12. Post Hoc Comparisons for RM Factor 1

		Mean Difference	SE	df	t	Cohen's d	p_{Holm}
Pretest 1	Pretest 2	-3.923	.043	38	-9.76	-1.122	< .001
	Pretest 3	-7.897	.072	38	-11.4	-2.260	< .001
	Posttest 1	-14.49	.127	38	-114.5	-4.145	< .001
	Postest 2	-2.87	.123	38	-169.9	-5.972	< .001
	Posttest 3	-26.59	.131	38	-203.0	-7.608	< .001
Pretest 2	Pretest 3	-3.974	.045	38	-88.71	-1.137	< .001

		Mean Difference	SE	df	t	Cohen's d	p_{Holm}
	Posttest 1	-1.56	.103	38	-103.0	-3.023	< .001
	Postest 2	-16.95	.104	38	-163.6	-4.849	< .001
	Posttest 3	-22.67	.106	38	-213.7	-6.485	< .001
Pretest 3	Posttest 1	-6.590	.088	38	-75.02	-1.885	< .001
	Postest 2	-12.97	.086	38	-15.8	-3.712	< .001
	Posttest 3	-18.69	.091	38	-205.1	-5.348	< .001
Posttest 1	Postest 2	-6.385	.087	38	-73.34	-1.827	< .001
	Posttest 3	-12.10	.072	38	-169.1	-3.463	< .001
Postest 2	Posttest 3	-5.718	.073	38	-78.33	-1.636	< .001

The results of the post hoc test in Table 12 show significant differences between all pairwise means ($p < .001$), with a consistent increase in scores at every stage. This indicates that students improved from the pretest to the third posttest with a very large effect size. The pretest and posttest results are further supported by field-based data collected directly from students after each treatment session. Specifically, descriptive data were obtained to examine how pre-service teachers' understanding enabled them to design mindful, meaningful, and joyful learning experiences, as shown in Table 13.

Tabel 13. Descriptive Statistics for LKM

				95% Confidence Interval Mean					
	Valid	Missing	Mean	Lower	Upper	Std. Deviation	Min	Max	Interpretaion
LKM 1	39	0	68.18	67.32	69.04	2.664	64.00	72.00	Effective
LKM 2	39	0	79.15	78.30	8.01	2.631	75.00	83.00	Effective
LKM 3	39	0	89.41	88.67	9.15	2.279	86.00	93.00	Very Effective
Total			**78.91**						**Effective**

Results of the descriptive analysis above indicate a significant and consistent trend of improvement in students' understanding at each stage of the intervention. This is evidenced by an increase in the average score from LKM 1 (68%, "Effective" category), rising to 79% ("Effective") at LKM 2, and peaking at 89% ("Very Effective") at LKM 3. With a total average LKM score of 79%, the overall result falls within the "Effective" category. The decrease in standard deviation from 2.664 to 2.279 indicates that the distribution of students' abilities became more even over time. Notably, the lowest score in LKM 3 (86.00) surpassed the highest score in LKM 1 (72.00), affirming the success of the learning process in elevating all students' competencies into the "Very Effective" category.

Table 14. Descriptive Statistics and Interpretation of Student Responses Based on 6C Indicators

Indicator	Question Item	Mean	Std. Deviation	Min	Max	Interpretation
Character	P1, P2, P3	3,12	.817	1.00	4.00	High
Citizenship	P4, P5, P6	3,09	.826	1.00	4.00	High
Collaboration	P7, P8, P9	3,14	.806	1.00	4.00	High
Communication	P1. P11	3,10	.834	1.00	4.00	High
Creativity	P12, P13	3,11	.826	1.00	4.00	High
Critical Thinking	P14, P15	3,17	.805	1.00	4.00	High
Total Average		**3,12**	**1.44***	**25.00***	**6.00***	**High**

Table 14 presents the descriptive statistics for students' responses regarding their understanding of 6C-integrated Deep Learning. Each item is denoted by "P" and grouped by 6C indicator. Results of the descriptive statistical analysis in Table 14 show that, overall, the achievement of the 6C indicators falls into the "High" category, with the total average also falling into the "High" category. This is demonstrated by the average scores for each indicator consistently exceeding 3.00 on the 1-4 Likert scale. The critical thinking indicator recorded the highest average (3.17), followed by collaboration (3.14), character (3.12), creativity (3.11), and communication (3.10). Meanwhile, the citizenship indicator obtained the lowest average (3.09), yet still remained in the "High" classification. These findings indicate that respondents possess solid 6C competencies, with critical thinking and collaboration standing out as the most dominant strengths compared to other aspects.

Upon confirming compliance with the analytical prerequisite assumptions, the subsequent step involved hypothesis testing to examine the relationships among the research variables. A non-parametric Spearman's rank correlation analysis was applied to measure the direction and strength of the relationships between students' initial cognitive abilities (pretest), their final conceptual understanding mastery (posttest), and their deep learning tendencies. The comprehensive details of this non-parametric correlation matrix are presented in Table 15.

Table 15. Shapiro–Wilk Test for Bivariate Normality Assumptions

			Shapiro-Wilk	p
Initial Understanding	-	Final Understanding	.982	.875
Initial Understanding	-	Deep Learning	.933	.005
Final Understanding	-	Deep Learning	.937	.008

Prior to hypothesis testing for correlation, a bivariate normality assumption check was conducted using the Shapiro–Wilk test to determine the appropriate statistical framework (parametric or non-parametric). As shown in Table 15, the variable pairs involving the Deep Learning psychological scale were not normally distributed ($p < .05$). Consequently, the correlation analysis was conducted using the non-parametric Spearman's rank correlation to ensure the appropriateness and validity of the statistical estimates.

Table 16. Non-Parametric Spearman's Rank Correlation Matrix Between Cognitive Performance and Deep Learning Tendencies

			Spearman's rho	p
Initial Understanding	-	Final Understanding	.988	< .001
Initial Understanding	-	Deep Learning	-.006	.971
Final Understanding	-	Deep Learning	-.006	.970

The Spearman's rank correlation analysis in Table 16 reveals a compelling pattern of interaction among the variables. Initial Understanding and Final Understanding show a strong, statistically significant positive correlation ($rho = .988$, $p < .001$), confirming linear and continuous cognitive development stability in the academic performance of PGMI students throughout the Basic Concepts of Social Studies course. By contrast, the Deep Learning (Likert-scale) score shows a consistently non-significant correlation approaching zero with both Initial Understanding and Final Understanding. From a theoretical-pedagogical standpoint, this statistical independence does not indicate a failure of the model; rather, it provides empirical evidence of a highly holistic and inclusive intervention. The 6C-Integrated Deep Learning framework implemented in the classroom functioned as a macro-learning ecosystem, or catalyst, rather than a narrowly targeted intervention. As substantiated by the preceding cognitive-impact analysis, it drove a substantial and uniform improvement in students' conceptual understanding, regardless of variation in students' subjective self-reports on the Deep Learning psychological scale. Accordingly, the model appears effective in developing cognitive abilities while reducing disparities in learning outcomes across the classroom.

DISCUSSIONS

Data analysis shows that implementation of the integrated 6C Deep Learning model had a significant effect on improving PGMI students' conceptual understanding in the Basic Concepts of Social Studies for MI/SD course. Statistical testing showed a consistent and significant increase in the mean score, from 65.26 at pretest to 91.85 at the final posttest. This finding indicates that the Deep Learning framework intervention was able to shift students' approach from rote memorization toward deep, structured conceptual mastery. This is consistent with global empirical findings on cognitive retention and retrieval-based learning in higher education reported by Biedermann et al. (2025) and further supported by Kovač et al. (2025). These preliminary quantitative trends suggest that the 6C-integrated Deep Learning model offers a promising pedagogical framework for supporting conceptual progress in pre-service teacher cohorts, although score gains should be interpreted with caution given the potential influence of test familiarity (practice effects) across repeated measurement cycles. This finding empirically supports the research of Efendi et al. (2025), who reported a substantial increase in learning achievement using a similarly concrete approach. This study extends that work by demonstrating that the effectiveness of Deep Learning is not limited to elementary-school classrooms, as emphasized by Gao et al. (2025), but is also critical for pre-service teacher education in fostering deep subject mastery, as noted by Mir (2025). The pre-service teachers' success in exceeding benchmark scores reflects their cognitive readiness to design meaningful social studies instruction in the future, supporting the premise of Law et al. (2025) that mastery experiences directly enhance instructional self-efficacy and pedagogical adaptability.

Bivariate correlation analysis was employed to further examine the model's overall effectiveness. The Spearman's rank correlation test revealed a divergence between cognitive progression and psychological self-report outcomes. The relationship between Initial Understanding and Final Understanding was strong and statistically significant (rho = .988, $p < .001$), confirming linear cognitive stability throughout the intervention, consistent with Hu and Cai (2026). By contrast, the Deep Learning psychological scale showed a non-significant correlation approaching zero with both Initial Understanding and Final Understanding. From a pedagogical perspective, this statistical independence indicates the model's inclusivity, suggesting that a structured macro-learning environment promotes equitable achievement regardless of variation in students' subjective psychological baseline, consistent with Padua (2025). Establishing structured, collaborative, and reflective learning environments drives equitable conceptual gains across diverse student cohorts (Fullan, 2025). The 6C-integrated Deep Learning model functions as a holistic macro-ecosystem rather than a rigid, linear path dependent on individual psychological profiles. Cognitive enhancement occurs inclusively, without disadvantaging students or limiting their contributions based on subjective engagement levels (Galimova et al., 2025). This structural shift advances educational leadership theory by demonstrating how standardized pedagogical interventions foster systemic institutional innovation and organizational learning (Jimoh, 2025).

Complex social dynamics and abstract pedagogical concepts in advanced Social Studies education often impose significant cognitive load on pre-service teachers, frequently inducing cognitive overload and academic anxiety during the learning process (Sunarto & Wardhanie, 2026). To address these affective barriers, the 6C Deep Learning model introduces structured affective stimulation embedded within collaborative student worksheets. The mindfulness components condition metacognitive self-awareness by allowing students to reflect without external judgmental pressure. This emotional grounding is consistent with neuroscience evidence suggesting that mindfulness practice can attenuate amygdala reactivity and redirect cognitive control toward the prefrontal cortex, supporting engagement across cognitive, affective, and psychomotor domains (Jiang, 2022). Balanced, domain-based instructional strategies further reinforce this cognitive-emotional transition (Mukherjee & Kittur, 2025). Concurrently, the joyful components serve as vital catalysts for sustaining academic resilience through collaborative problem-solving, dynamics that flourish particularly well in open, outdoor educational settings (El-aasar et al., 2024). Ultimately, cultivating such a supportive affective environment fosters significantly higher cognitive engagement among learners (Zhao et al., 2025).

Figure 3. Classroom Documentation of the 6C-Integrated Deep Learning Model

The integration of mindful, meaningful, and joyful principles into instructional design substantially strengthens students' conceptual literacy (Figure 3). Empirical evaluation through the Student Worksheets (Lembar Kerja Mahasiswa, LKM) demonstrated that overall learning effectiveness reached 89%, placing it in the "Very Effective" category. This finding suggests that mitigating psychological anxiety enables pre-service teachers to interpret, evaluate, and regulate their emotional states during complex learning tasks (Chotimah & Fantofik, 2025). Effective emotional regulation during digital adoption further ensures that technological integration enhances, rather than hinders, pedagogical capacity (Li et al., 2025). Empirical progression captured through the Student Worksheets (LKM 1, LKM 2, and LKM 3) directly addresses the second research question, concerning pre-service teachers' practical instructional-design mastery. The continuous score increase across LKM 1 (M = 68.18), LKM 2 (M = 79.15), and LKM 3 (M = 89.41) demonstrates that structured group scaffolding effectively transforms theoretical understanding into concrete lesson-planning capability. This performance trend reinforces previous findings on task-centered pedagogical design in teacher preparation (Dong, 2022).

Developing higher-order thinking skills through the 6C framework is essential for preparing future educators to meet 21st-century instructional standards. Student performance across the 6C indicators yielded a high overall average of 3.12 out of 4.00, with Critical Thinking emerging as the highest-performing dimension at 3.17. These findings extend previous research on Deep Learning implementation in primary-education settings (Ramadan et al., 2026). While prior studies focused on elementary students, this research indicates that prospective teachers must achieve solid conceptual mastery before they can transmit these skills effectively. Skill transmission appears most successfully operationalized when guided by structured, task-based learning frameworks. Furthermore, embedding these interactive frameworks into core Social Studies education optimizes practical skill application in real-world contexts (Inganah et al., 2023).

Comprehensive professional readiness among prospective educators relies more heavily on core pedagogical competencies than on technical infrastructure alone. Regression models indicate that 21st-century skills account for 37.2% of the variance in professional teacher readiness, outperforming technological adoption alone as a predictor (Fitrah et al., 2025). With a Collaboration score of 3.14, the 6C Deep Learning model demonstrates a strong capacity to cultivate collective agency among students. This collaborative strength fosters a form of pedagogical resilience that artificial intelligence systems cannot replicate, addressing a central challenge in modern smart-learning environments (Mhlongo et al., 2023). Consequently, prioritizing humanistic teaching capabilities remains essential to fully realizing the digital capacity of educational institutions (Timotheou et al., 2023).

Achieving uniform conceptual mastery across student cohorts demonstrates the inclusive nature of the 6C Deep Learning model. The stability of learning gains was reflected in the progressive reduction of score variance, with standard deviations decreasing from 2.664 to 2.279. This narrowing performance gap underscores the efficacy of reflective instructional design in accommodating diverse learning profiles (Musfirah et al., 2025). Overall, the 6C-integrated Deep Learning framework offers a promising conceptual foundation for reimagining pre-service teacher preparation for the artificial intelligence era. The intervention appears to empower prospective educators to redefine their professional identity as humanistic learning architects (Nguyen et al., 2025). In the long term, this pedagogical transformation may generate positive-sum dynamics that sustain continuous educational innovation.

CONCLUSION

This study addressed its primary objective by demonstrating that implementation of the 6C-integrated Deep Learning model substantially improved pre-service elementary teachers' conceptual understanding in the Basic Concepts of Social Studies course, as evidenced by a significant mean score progression from 65.26 to 91.85. The primary theoretical novelty and contribution of this research lie in demonstrating that the efficacy of Deep Learning frameworks extends beyond elementary school classrooms into pre-service teacher training, serving as an effective pedagogical mechanism for addressing teacher unpreparedness. By synthesizing mindful, meaningful, and joyful learning principles, this model effectively mitigates academic anxiety and helps address psychological barriers, leading to equitable cognitive gains across diverse student cohorts. Furthermore, this study offers a new perspective on teacher professional-identity reconstruction within Madrasah Ibtidaiyah Teacher Education at UIN Sunan Kalijaga Yogyakarta, redefining prospective educators from passive content deliverers into humanistic learning macro-ecosystem architects equipped with essential 21st-century competencies. This research is subject to notable methodological limitations that require explicit acknowledgment. A primary limitation involves external validity, as the study drew upon a small, purposively selected sample (N = 39) confined to a single class, academic program, and institutional context. Consequently, the findings should be presented as preliminary empirical evidence that may partly reflect institution-specific characteristics or baseline student profiles, rather than the intervention alone. Furthermore, the single-group time-series design, which lacks a parallel control cohort, cannot fully decouple intervention effects from natural maturation or test familiarity (practice effects). Therefore, future research should conduct rigorous replications across multiple classes, diverse university settings, and distinct academic disciplines, using randomized controlled designs to test the cross-contextual scalability and long-term retention of this model. The empirical insights derived from this study offer several strategic implications for policy, curriculum development, and educational practice. For higher education policymakers and curriculum developers, future policy should prioritize the systematic integration of 21st-century 6C competencies and Deep Learning frameworks into pre-service teacher training, rather than focusing solely on technological infrastructure adoption. For teacher educators and university lecturers, it is suggested that instructional design actively incorporate mindful and reflective group learning activities to cultivate students' critical thinking and collective agency. Finally, for pre-service elementary teachers, continuous engagement with reflective Deep Learning practices is essential to building the cognitive resilience, empathy, and adaptive professionalism needed to navigate the evolving educational landscape in the artificial intelligence era.

ACKNOWLEDGMENT

The authors express their sincere gratitude to [Institution] for the support and facilities provided during the conduct of this study. The authors also thank the pre-service teachers of the PGMI programme who participated in this research for their time and willingness to take part, and the lecturers whose guidance and constructive feedback contributed to the development of this work.

AUTHOR'S DECLARATIONS

Authors' Contributions

RPS: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft. SYR: Conceptualization, Supervision, Writing – review & editing. BSA: Project administration, Supervision, Writing – review & editing. ETA: Methodology, Resources, Writing – review & editing. FMF: Writing – review & editing. HS: Writing – review & editing. SAO: Writing – review & editing. All authors read and approved the final manuscript.

Funding Statement

This research received no external funding.

Availability of Data and Materials

The datasets generated and/or analyzed during the current study are stored by the authors and are available from the corresponding author, RPS, upon reasonable request.

Competing Interests

The authors declare that they have no competing interests.

REFERENCES

Ali, E. Y. (2025). The effectiveness of AI-based education management systems in implementing deep learning curriculum in elementary schools. *Journal of Integrated Elementary Education, 5*(2), 339–352. https://doi.org/10.21580/jieed.v5i2.28004

Apriliant‌y, E. (2025). In-depth learning policy analysis in the Indonesian education system with the SMART approach. *Jurnal Pedagogi dan Pembelajaran*, *8*(3), 540–549. https://doi.org/10.23887/jp2.v8i3.102638

Aridan, M., Hijriyah, U., Khabibjonovna, K. N., Geng, H., Azad, I., & Elyas, T. (2024). Pre-service language teachers' readiness for deep learning approaches: Insights from a cross-regional study in Asia. *LLT Journal: A Journal on Language and Language Teaching*, *28*(2), 948–971. https://doi.org/10.24071/llt.v28i2.12274

Ariga, S. (2023). Implementasi kurikulum merdeka pasca pandemi COVID-19 [Implementation of the Merdeka Curriculum in the Post-COVID-19 Pandemic Era]. *Edu Society: Jurnal Pendidikan, Ilmu Sosial dan Pengabdian Kepada Masyarakat*, *2*(2), 662–670. https://doi.org/10.56832/edu.v2i2.225

Arina, I., & Isyanto, P. (2025). Teachers' pedagogical understanding in the implementation of independent curriculum in the context of deep learning. *Jurnal Ilmiah Global Education*, *6*(2), 426–435. https://doi.org/10.55681/jige.v6i2.3778

Asitah, N., Anam, F., Ismanto, H., Wahyudi, A., & Adi, T. (2026). Implementasi model pembelajaran deep learning dalam kurikulum merdeka: Studi fenomenologis guru sekolah dasar [Implementation of the Deep Learning Instructional Model in the Merdeka Curriculum: A Phenomenological Study of Elementary School Teachers]. *Nusantara Educational Review*, *4*(1), 1–11. https://doi.org/10.55732/ghqj5z66

Baihaqi, M. A., Prayitno, H. J., Ishartono, N., & Titi, S. S. (2025). Reimagining 21st-century higher education: A literature-based exploration of deep learning for cognitive, social, and emotional skill development. *Journal of Deep Learning*, *1*(2), 139–168. https://doi.org/10.23917/jdl.v1i2.11600

Biedermann, D., Breitwieser, J., Nobbe, L., Drachsler, H., & Brod, G. (2025). Memorizing plans with an app: Large individual differences in the effectiveness of retrieval-based and generative learning activities in a naturalistic context. *Learning and Individual Differences, 118,* 102641. https://doi.org/10.1016/j.lindif.2025.102641

Bihag, J. G. Q., Celso, R. B., Arabbi, A. A., Ladjakahal, M. I., Idlana, N. J., Karim, S. N. I., Sahidul, Z. A., Tandih, S. A., & Kunting, A. F. (2025). Instructional practices of social studies teachers in basic education. *Journal of Health Research and Society*, *4*(1), 93–106. https://doi.org/10.34002/jhrs.v4i1.114

Bulkis, I., Tahir, M., & Sakkir, G. (2025). EFL teachers' implementation of 6C skills (critical thinking, creativity, collaboration, communication, citizenship, and character) in 21st-century skills. *EduLine: Journal of Education and Learning Innovation*, *5*(2), 262–273. https://doi.org/10.35877/454ri.eduline3927

Cahyanto, B. (2025). Implementation of deep learning for strengthening reading literacy in elementary school. *Ghancaran: Jurnal Pendidikan Bahasa dan Sastra Indonesia*, *7*(1), 219–235. https://doi.org/10.19105/ghancaran.v7i1.18892

Cheng, Q., Zhou, X., Shu, L., & He, X. (2026). Effects of multicultural professional development and English learner percentage on STEM teachers' instructional quality: A path analysis of the mediating role of teacher self-efficacy in multicultural classrooms. *Journal of Educational Psychology, 118*(1), 45–62. https://doi.org/10.1016/j.tate.2026.105438

Chotimah, S. C., Suhartono, S., & Fantofik, D. (2025). Implementasi pembelajaran mendalam: Berkesadaran (mindful), bermakna (meaningful), dan menggembirakan (joyful) [Implementation of Deep Learning: Mindful, Meaningful, and Joyful Learning]. *An-Nuha*, *5*(4), 673–682. https://doi.org/10.24036/annuha.v5i4.758

Creswell, J. W., & Creswell, J. D. (2023). *Research design: Qualitative, quantitative, and mixed methods approaches* (6th ed.). SAGE Publications.

Dedy, A., Laksana, R. B., & Utami, S. A. (2025). Penerapan perangkat pembelajaran dengan pendekatan deep learning pada mahasiswa semester 3 program studi PGSD Universitas PGRI Palembang [Implementation of Deep Learning Approach-Based Learning Materials among Third-Semester Students of the Elementary School Teacher Education Program at Universitas PGRI Palembang]. *Jurnal Ilmiah Pendidikan Dasar*, *10*(4), 215–222. https://doi.org/10.23969/jp.v10i04.38795

Dong, W. (2022). *Building 6C's (critical thinking, collaboration, communication, creativity, culture, connectivity) in the Chinese learning classroom* [Report, Utah State University]. Graduate Studies, Utah State University. https://digitalcommons.usu.edu/gradreports/1654/

Efendi, R., Siswanto, D. H., & Saputra, S. A. (2025). Deep learning approach to teaching multiplication concepts using coin media: Classroom action research in elementary school. *Jurnal Padamu Negeri, 2*(2), 87–97. https://doi.org/10.69714/xaewmx28

El-aasar, M., Shafik, Z., & Abou-bakr, D. (2024). Outdoor learning environment as a teaching tool for integrating education for sustainable development in Kindergarten, Egypt. *Ain Shams Engineering Journal, 15*(4), 102629. https://doi.org/10.1016/j.asej.2024.102629

Fitrah, M., Sofroniou, A., Yarmanetti, N., Ismail, I. H., Anggraini, H., Nissa, I. C., Widyaningrum, B., Khotijah, I., Kurniawan, P. D., & Setiawan, D. (2025). Are teachers ready to adopt deep learning pedagogy? The role of technology and 21st-century competencies amid educational policy reform. *Education Sciences*, *15*(10), 1344. https://doi.org/10.3390/educsci15101344

Fullan, M. (2025). *The new meaning of educational change* (6th ed.). Teachers College Press.

Galimova, E. G., Sergeeva, O. V., Zheltukhina, M. R., Sokolova, N. L., Zakharova, V. L., & Drobysheva, N. N. (2025). Mobile learning in science education to improve higher-order thinking skills and communication skills: Scoping review. *Frontiers in Communication*, *10,* 1624012. https://doi.org/10.3389/fcomm.2025.1624012

Gao, H., Yu, D., Yang, L., & Zhou, M. (2025). Research on strategies for digital technology-enabled flipped classrooms based on deep learning theory. *International Educational Research*, *8*(6), 32–41. https://doi.org/10.30560/ier.v8n6p32

Hadevi, M., A, H., Nelian, & Warniati. (2026). Inovasi dan teknologi dalam pendidikan: Studi kasus Finlandia, Jepang, Singapura dan Indonesia [Innovation and Technology in Education: A Case Study of Finland, Japan, Singapore, and Indonesia]. *RIGGS: Journal of Artificial Intelligence and Digital Business*, *4*(4), 9412–9420. https://doi.org/10.31004/riggs.v4i4.4095

Hermita, N., Gusmida, S. B., R., Jaya Adi Putra, M., & Asiah, N. (2025). Deep learning pedagogy through STEM coding for elementary teachers: Strengthening computational thinking and curriculum implementation readiness. *Jurnal Kreasi*, *5*(3), 112–125. https://doi.org/10.58218/kreasi.v5i3.2004

Hu, H., & Cai, C. (2026). Effects of interpersonal interactions on the teacher beliefs of English pre-service teachers in China: The mediating role of self-efficacy. *Acta Psychologica*, *263,* 106421. https://doi.org/10.1016/j.actpsy.2026.106421

Hunaepi, & Suharta, I. G. P. (2024). Transforming education in Indonesia: The impact and challenges of the Merdeka Belajar curriculum. *Path of Science*, *10*(6), 3001–3012. https://doi.org/10.22178/pos.105-31

Inganah, S., Darmayanti, R., & Rizki, N. (2023). Problems, solutions, and expectations: 6C integration of 21st century education into learning mathematics. *JEMS: Jurnal Edukasi Matematika dan Sains*, *11*(1), 220–238. https://doi.org/10.25273/jems.v11i1.14646

Jiang, R. (2022). Understanding, investigating, and promoting deep learning in language education: A survey on Chinese college students' deep learning in the online EFL teaching context. *Frontiers in Psychology*, *13*, 955565. https://doi.org/10.3389/fpsyg.2022.955565

Jimoh, A. L. (2025). The effect of sustainable leadership on institutional innovation in higher education: The role of organizational learning culture. *International Journal of Educational Management*, *39*(7), 1647–1661. https://doi.org/10.1108/IJEM-07-2025-0552

Karimulloh, K., Khaerudin, K., & Siregar, E. (2026). An AI-Driven Deep Learning Adaptive Curriculum Model (DNCL) for Indonesian Secondary Schools: Evidence from a Single-Site Intervention. *Nusantara: Jurnal Pendidikan Indonesia*, *6*(1), 26-40. https://doi.org/10.62491%2Fnjpi.2026.v6i1-3

Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi. (2022). *Buku saku tanya jawab Kurikulum Merdeka [Merdeka Curriculum Q&A Pocketbook]*. Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi. https://www.satudik.id/referensi/bs_ikm.pdf

Kenaphoom, S. (2024). Innovations in education: Pathways to 21st century learning. *Asian Journal of Humanities and Social Innovation*, *1*(2), 46–57. https://doi.org/10.14456/ajhsi.2024.10

Kovač, V. B., Nome, D. Ø., Jensen, A. R., & Skreland, L. L. (2025). The why, what and how of deep learning: Critical analysis and additional concerns. *Education Inquiry*, *16*(2), 237–253. https://doi.org/10.1080/20004508.2023.2194502

Law, J. M., Boese, K., Roy, S., & Boese, A. S. (2025). Empowering future literacy instructors: The role of mastery experiences in pre-service teachers' literacy knowledge and self-efficacy. *Journal of Early Childhood Teacher Education*, *46*(1), 1–26. https://doi.org/10.1080/10901027.2025.2538577

Li, J., Bai, B., & Liu, H. (2025). When technology meets emotions: Exploring preschool teachers' emotion profiles in technology use. *Computers & Education, 236,* 105355. https://doi.org/10.1016/j.compedu.2025.105355

Lin, K. Y., Ku, C. J., Wei, H. T., Yu, K. C., & Williams, P. J. (2025). Processes, challenges, and teacher roles in developing and implementing collaborative STEM curricula: Case studies of two Taiwanese schools. *International Journal of STEM Education*, *12*, Article 15. https://doi.org/10.1186/s40594-025-00545-3

Mhlongo, S., Mbatha, K., Ramatsetse, B., & Dlamini, R. (2023). Challenges, opportunities, and prospects of adopting and using smart digital technologies in learning environments: An iterative study. *Heliyon*, *9*(6), 16348. https://doi.org/10.1016/j.heliyon.2023.e16348

Mir, A. H. (2025). Learner-centered pedagogies: Transforming education for the 21st century. *Journal of Accounting Research, Utility Finance and Digital Assets (JARUDA)*, *4*(4), 383–387. https://jaruda.id/index.php/go/article/view/217

Mohammad Zadeh, M., & Ferrari, R. (2026). Enhancing deep learning and workload management in online education: The power of scaffolded weekly assessments. *International Journal of*

Teaching and Learning in Higher Education, *36*(1), 45–58. https://doi.org/10.7771/1812-9129.1131

Mukherjee, S., & Kittur, J. (2025). Learning through cognitive, affective, and psychomotor domains: Understanding undergraduate engineering students' perspectives in the United States. *Engineering Education Review*, *3*(3), 1–11. https://doi.org/10.54844/eer.2025.0916

Musfirah, Kamaruddin, Syawaluddin, A., Zainal, Z., & Burhan, I. (2025). Enhancing primary school teachers competence through training on the implementation of deep learning in Barru Regency. *HELP: Journal of Community Service*, *2*(2), 101–112. https://doi.org/10.62569/hjcs.v2i2.200

Muttaqin, I. (2022). Necessary to increase teacher competency in facing the artificial intelligence era. *Journal of Islamic Education*, *6*(2), 115–128. https://doi.org/10.35723/ajie.v6i2.460

Nguyen, Y. T., Clapano, B. G., Grace, B., & Oblina, C. (2025). Reimagining teacher roles in the age of AI: Perspectives from Vietnamese classrooms. *International Journal of Multidisciplinary Research and Publications*, *7*(11), 92–96. https://www.researchgate.net/publication/391284069_Reimagining_Teacher_Roles_in_the_Age_of_AI_Perspectives_from_Vietnamese_Classrooms

Nurhidayani, Novelina, L., Niami, B. P., Setiawati, M., & Hayati, N. (2025). Peran guru dalam pengembangan dan implementasi kurikulum Pendidikan [The Role of Teachers in Curriculum Development and Implementation]. *Jurnal Intelek Insan Cendekia*, *2*(5), 145–156. https://jicnusantara.com/index.php/jiic/article/view/3613

Padua, D. (2025). Artificial intelligence and quality education: The need for digital culture in teaching. *Journal of Educational, Cultural and Psychological Studies (ECPS Journal)*, *30,* 181–193. https://doi.org/10.7358/ecps-2024-030-padd

Putri, I. N., & Fitria, H. (2023). Pengaruh efikasi diri guru dan iklim organisasi terhadap produktivitas kerja guru SD Negeri se-Kecamatan Rantau Panjang Kabupaten Ogan Ilir [The Effects of Teacher Self-Efficacy and Organizational Climate on the Work Productivity of Public Elementary School Teachers in Rantau Panjang District, Ogan Ilir Regency]. *JIIP - Jurnal Ilmiah Ilmu Pendidikan*, *6*(9), 6933–6939. https://doi.org/10.54371/jiip.v6i9.2680

Qomariyah, N., & Maghfiroh, M. (2022). Transisi Kurikulum 2013 Menjadi Kurikulum Merdeka: Peran dan Tantangan dalam Lembaga Pendidikan [Transition of the 2013 Curriculum to the Independent Curriculum: Roles and challenges in educational institutions]. *Gunung Djati Conference Series*, *10,* 105–115. https://conferences.uinsgd.ac.id/index.php/gdcs/article/view/1061

Ramadan, R., Rizal, R., Pahriadi, P., Nashrullah, N., Kamil, M. N. A., & Wilade, S. (2026). Problem-based learning with a deep learning orientation in elementary science and social studies: Fostering conceptual understanding and student engagement in Grade IV. *Journal of Innovation and Research in Primary Education*, *5*(2), 2736-2746. https://doi.org/10.56916/jirpe.v5i2.3624

Rivera, J. P. R., Sinsay-Villanueva, L. M., Tanyag, I. H., Berroya, J. D., Garcia, G. D. V., & Lim, V. L. (2025). *Revitalizing the Philippine education system: Facilitating access and participation to in-service training (INSET) and teacher professional development (TPD)* (Discussion Paper No. 2025-14). Philippine Institute for Development Studies. https://doi.org/10.62986/dp2025.14

Rizkasari, E., Prihatsari, E. B., & Wicaksono, A. G. (2026). Teachers' perceptions of deep learning pedagogy in Indonesian primary schools: Evidence from the Wahidin Sudiro Husodo Cluster. *EduBase: Journal of Basic Education*, *7*(1), 75–84. https://doi.org/10.47453/edubase.v7i1.3855

Santosa, B. E., Sukmawati, F., Ridhani, J., Trisnaningsih, S., & Prihatin, R. (2025). Teachers' readiness to implement the deep learning approach in merdeka curriculum: An analysis based on psychopedagogical characteristics. *JTP - Jurnal Teknologi Pendidikan*, *27*(3), 765–773. https://doi.org/10.21009/jtp.v27i3.58841

Savitri, S. I., Kawuryan, S. P., Senen, A., Firdaus, F. M., & Putri, A. A. (2026). Learning motivation and student engagement as predictors of social studies understanding in pre-service elementary teachers. *International Journal of Learning Reformation in Elementary Education, 5*(1), 232–244. https://doi.org/10.56741/IISTR.ijlree.001773

Setiyowati, E., Puspita, A. M. I., & Mariana, N. (2025). Teachers' pedagogical competence in designing deep learning and HOTS assessment in elementary schools. *Journal of Innovation and Research in Primary Education, 4*(4), 401–415. https://doi.org/10.56916/jirpe.v4i4.2633

Shen, G., Wu, W., & Huang, W. (2025). Tackling the AI-creativity paradox: How educational innovation and knowledge unlocks positive-sum dynamics. *Journal of Innovation & Knowledge*, *10*(6), Article 100816. https://doi.org/10.1016/j.jik.2025.100816

Sumintono, B., & Widhiarso, W. (2014). *Aplikasi model Rasch untuk penelitian ilmu-ilmu sosial*. Trim Komunikata.

Sunarto, M. J. D., & Wardhanie, A. P. (2026). Artificial intelligence and hybrid learning in education: A conceptual synthesis for deep learning (6C). *Futurity of Social Sciences*, *4*(2), 26–41. https://doi.org/10.57125/fs.2026.06.20.02

Tijani, B. E., & Adeduyigbe, A. M. (2026). Transforming science education: A systematic review of evidence-based strategies for cultivating 21st-century skills in STEM education. *Journal of Research in Environmental and Science Education*, *3*(1), 8–23. https://doi.org/10.70232/jrese.v3i1.37

Timotheou, S., Miliou, O., Dimitriadis, Y., Sobrino, S. V., Giannoutsou, N., Cachia, R., Monés, A. M., & Ioannou, A. (2023). Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation. *Education and Information Technologies*, *28*(6), 6695–6726. https://doi.org/10.1007/s10639-022-11431-8

Ursula, A., Asrin, Rahmatih, A. N., & Istiningsih, S. (2025). Pengaruh model pembelajaran Cooperative Integrated Reading and Composition (CIRC) terhadap kompetensi 6C siswa kelas 4 SD Negeri Gugus IV Kecamatan Selaparang [The Effect of the Cooperative Integrated Reading and Composition (CIRC) Learning Model on the 6C Competencies of Fourth-Grade Students in Public Elementary Schools in Cluster IV, Selaparang District]. *JPAP: Jurnal Praktisi Administrasi Pendidikan, 9*(2), 61–69. https://doi.org/10.29303/jpap.v9i2.988

Wahab, A., Junaedi, & Azhar, M. (2021). Efektivitas pembelajaran statistika pendidikan menggunakan uji peningkatan N-gain di PGMI [The Effectiveness of Educational Statistics Learning as Measured by the N-Gain Test in the PGMI (Islamic Elementary School Teacher Education Study Program)]. *Jurnal Basicedu*, *5*(5), 524–532. https://doi.org/10.31004/basicedu.v5i2.845

Warnia, T. W., Oktaviana, F., & Fitriani, D. (2026). Deep learning in Indonesian education: Conceptual foundations, policy frameworks, and implementation. *Sintaksis: Publikasi Para Ahli Bahasa dan Sastra Inggris*, *4*(1), 62–82. https://doi.org/10.61132/sintaksis.v4i1.2499

Zhao, J., Wu, Y., Deng, R., Xu, S., Gao, J., & Burke, A. (2025). A survey of autonomous driving from a deep learning perspective. *ACM Computing Surveys*, *57*(10), Article 214. https://doi.org/10.1145/3729420