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The Learning Progression of Elementary School Students' Scientific Literacy and Numeracy on SDG 13 Climate Action During STEM Learning

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ABSTRACT

Purpose - This study examines a STEM instructional intervention that fosters students' scientific literacy and numeracy within the context of SDG 13: Climate Action.

Methodology - A quasi-experimental design with a time-series approach was employed to observe the progression of a single fourth-grade student group closely. Four pre-tests and four post-tests, using equivalent multiple-choice test instruments, were subjected to validity and reliability testing. Time-series analysis was used to examine the learning progression of scientific literacy and numeracy achievement, suggesting an upward trend.

Findings - The results revealed a significance value of 0.024 < 0.05, indicating that students' scientific literacy and numeracy performed significantly better following STEM instruction compared to before the intervention. Furthermore, students' starting point was 7.35, which then declined during the pre-test phase. Following STEM instruction, the mean score for students' scientific literacy and numeracy increased to 7.7, ultimately reaching 9.08. The trajectory formed across each data point indicates an upward trend in scores. Additionally, based on Segmented Regression analysis, scores declined by 0.366 points per period before the intervention. At the point of intervention, the score immediately increased by 1.164 points. Following the intervention, the trend increased by 0.787 points per period. These findings indicate an immediate improvement in scores upon the delivery of the intervention.

Contribution - Accordingly, STEM instruction has been proven effective as an alternative instructional model for teaching scientific literacy and numeracy, enhancing the quality of learning while simultaneously preparing students to meet global challenges. Future research is encouraged to further develop Education for Sustainable Development (ESD) within other contexts or variables.

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INTRODUCTION

The Sustainable Development Goals (SDGs) are a set of global goals agreed upon by the United Nations (UN) to address challenges such as hunger, climate change, and the quality of education. In 2015, all UN member states adopted the 2030 Agenda, which encompasses 17 Sustainable Development Goals (SDGs). The SDGs came into effect on January 1, 2016, and are set to remain in force through 2030 (Ruiz-Garzón et al., 2021). In Indonesia, the SDGs continue to be actively promoted, with various stakeholders working to achieve these noble objectives. One of the critical foundations for advancing the SDGs in Indonesia is through elementary education. A strong educational foundation will equip the next generation of Indonesians with the competencies, sense of ownership, and responsibility necessary for the nation's prosperity. Among the 17 goals outlined in the SDGs, one in particular has drawn researchers' attention for its potential integration with quality education — namely, Goal 13, commonly referred to as SDG 13, which pertains to Climate Action.

The issue of climate change has become a global concern, as safeguarding Earth's security and sustainability is a shared responsibility. The increase in atmospheric CO_2 emissions, along with rising precipitation levels, has prompted various stakeholders to conduct routine measurements of greenhouse gas concentrations (Gernowo et al., 2012). Climate change occurs as a result of global warming — the rise in temperatures across the atmosphere, oceans, and land surface of the Earth — caused by the trapping of solar heat by greenhouse gases generated by human activities, such as vehicular emissions, industrial operations, and burning for deforestation. The accumulation of these greenhouse gases increases global temperatures, which in turn contributes to more frequent and severe natural disasters and to environmental degradation resulting from the misuse of natural resources. Although climate change manifests at the local scale, its impacts are global in nature and pose a significant threat to the quality of life of both present and future generations, thereby necessitating sustained efforts such as emissions reduction, waste recycling, and reforestation (Lestari et al., 2024; Ruiz-Garzón et al., 2021).

One of the targets established by the UNDP under SDG 13 is to strengthen education, raise awareness, and build individual and institutional capacity to mitigate, adapt to, reduce the impacts of, and provide early warning of climate change (UNDP, 2016). Knowledge of climate change should be introduced to students from an early age so they develop a genuine sense of awareness and concern about the issue. Schools need to design educational programs focused on climate change in order to reinforce and complement the existing curriculum (Baga et al., 2024). Climate-based education integrated with the concept of sustainable development needs to be expanded across all subject areas and implemented comprehensively within the curriculum (Arwan, 2022).

Education is a key driver of pro-environmental behavior, positioning teachers as agents of change who can raise awareness of sustainability. Therefore, the SDGs need to be consciously integrated into higher education and school curricula through innovative instructional methods. Further studies are needed to broaden the connections between the SDGs and other environmental issues and to strengthen the teaching of sustainable development for pre-service teachers (Margot & Kettler, 2019). However, teachers still have a limited understanding of the SDGs (Azizah et al., 2024). Meanwhile, teachers must continually strive to enhance students' higher-order thinking skills and intellectually motivate them through scientific literacy. An understanding of the interrelationships among science, technology, and societal practices helps individuals advance their scientific literacy at both the personal and global scales (Lestari et al., 2024). Empirical evidence underscores the urgency of this issue: Indonesia's scores in the 2022 PISA assessment declined across all three domains — mathematics (366), reading (359), and science (383) — remaining well below the OECD average and reflecting a persistent gap in students' scientific literacy and numeracy that demands targeted instructional intervention (OECD, 2023).

One approach to integrating knowledge of the importance of climate change into school-based learning is through literacy activities within STEM instruction. STEM learning is an instructional approach that integrates science, technology, engineering, and mathematics. Enhancing students' scientific and technological literacy requires a shift from content-based teaching toward an approach more oriented to students' needs and motivations, in which science is used as a vehicle for learning by emphasizing social and scientific issues relevant to the community's lives (Holbrook & Rannikmae, 2007). STEM instruction has been demonstrated to develop students' mastery of specific competencies. For instance, research on implementing STEM-SDGs instruction has shown that it improves students' scientific communication skills (Afkarina et al., 2024). The enhancement of scientific literacy is influenced by the use of innovative media that incorporates the latest technologies and concepts familiar to students, thereby helping them develop rational thinking and conceptualize abstract scientific ideas more concretely (Wulandani & Suryawan, 2024). Furthermore, research integrating physics learning with climate action, grounded in the principles of the SDGs, has proven effective in building environmental awareness and preparedness for global change (Hartati & Hariyono, 2020). Prior to students developing key competencies in Education for Sustainable Development (ESD), their literacy regarding SDGs-related issues must be cultivated through integrated instruction. The interdisciplinary nature of STEM aligns with the complexity of climate change, which involves scientific understanding, technological solutions, engineering design, and mathematical modeling, making it a particularly relevant instructional framework for developing climate action literacy.

Two types of literacy are particularly noteworthy for examination in the context of SDG 13: Climate Action, namely scientific literacy and mathematical literacy (numeracy). Scientific literacy refers to the ability to understand scientific concepts and their application. Students with strong scientific literacy can apply their knowledge to address a wide range of problems in everyday life at the personal, social, and global levels (OECD, 2009). Numeracy, on the other hand, is defined as the skill of processing, communicating, and comprehending information related to numbers. Mastering numeracy in adults is a construct that refers to how individuals manage various mathematical, quantitative, and statistical demands in adult life (Gal et al., 2020). Central to this study is the concept of learning progression, which describes the journey through which students acquire, refine, apply, and develop their skills, knowledge, and understanding across increasingly challenging situations (Braund, 2008). It emphasizes the importance of connecting prior ideas and experiences with new ones through coherently designed instructional materials (Fortus & Krajcik, 2012), with its outcomes manifested as a map of students' cognitive changes as they engage with specific concepts over time (Anggoro et al., 2019). Examining learning progression — rather than merely measuring pre- and post-test differences — provides a more nuanced and sequentially accurate picture of how students develop scientific literacy and numeracy throughout the instructional process. The enhancement of students' scientific literacy and numeracy, observed through the lens of learning progression, can be facilitated by applying an appropriate Science, Technology, Engineering, and Mathematics (STEM)-based approach (Aprilia et al., 2023).

SDGs-related issues are still rarely addressed in student learning, as these topics have yet to stand as independent subject matter. They must instead be integrated into relevant topics within specific disciplines, such as Science and Social Studies (IPAS) or Mathematics. Moreover, elementary and Islamic elementary school (SD/MI) teachers remain largely unfamiliar with the SDGs. Meanwhile, scientific literacy and numeracy about SDGs issues — particularly Climate Action — are urgently needed by students in light of the goals of sustainable development. While prior studies have examined STEM instruction in relation to scientific communication skills (Afkarina et al., 2024) or environmental caring character (Hartati & Hariyono, 2020), none have specifically investigated the learning progression of both scientific literacy and numeracy simultaneously within the context of SDG 13: Climate Action at the elementary school level using a time-series quasi-experimental design. This gap constitutes the research problem addressed in the present study. The novelty of this study lies in its integration of scientific literacy and numeracy development within STEM instruction, specifically situated in SDG 13: Climate Action, examined through a learning progression lens using an Interrupted Time Series analytical framework at the elementary school level in Indonesia. Therefore, this study aims to examine the learning progression of students' scientific literacy and numeracy during STEM instruction on SDG 13: Climate Action.

METHODOLOGY

Research Design

This Quasi-Experimental study employs a Time-Series Design to observe the effects of STEM instruction repeatedly, both before and after the treatment. Data on students' learning progression of scientific literacy and numeracy related to SDG 13: Climate Action were collected from a single treatment group. An improvement or learning progression is considered to have occurred when a significant increase in scores is observed across a series of post-tests compared to the stable scores obtained across a series of pre-tests (Fraenkel et al., 2012). In this study, pre- and post-tests were administered repeatedly at a minimum of 4 measurement points using the same research instrument. Meanwhile, the treatment was delivered through a single instructional sequence comprising at least two learning sessions. The design of this time-series study is illustrated in Figure 1. In this figure, O_1 through O_4 represent the four repeated pre-test measurements administered prior to the instructional treatment, X denotes the STEM instructional sequence, and O_5 through O_8 represent the four repeated post-test measurements conducted after the treatment.

O_1	O_2	O_3	O_4	X	O_5	O_6	O_7	O_8

Figure 1. Quasi-Experimental Time-Series Design

Participant

This study was conducted at a private school on the outskirts of Salatiga City, Central Java Province. Despite its peripheral location, the characteristics of its students are not significantly different from those attending schools in the urban center, as they generally perform above the class average. The school comprises 36 class groups, with six at each grade level—the selection of a single fourth-grade class as the research sample was purposive. The decision to employ a single-class sample was based on two rationales. First, the quasi-experimental time-series design requires only one class, yet allows detailed measurement of students' scientific literacy and numeracy before and after the treatment is administered. Second, among the six available class groups, the selected class was chosen because its students were sufficiently engaged in science learning through integrated, technology-based instruction.

Data Collection

The development of the STEM instructional scenario follows a sequence of learning steps, beginning with problem formulation and then exploring solutions through technology. Subsequently, students design the technology to be developed, followed by the process of producing the technological product. Upon completion of the product, testing is conducted to evaluate its effectiveness, followed by refinement through revisions to the initial design to improve the resulting technology's quality and functionality (Widodo, 2021). In addition, student worksheets (LKPD) structured around the STEM instructional sequence were developed to facilitate learning and support students' scientific literacy and numeracy. In the subsequent step, data-collection instruments, in the form of tests, were developed to measure students' scientific literacy and numeracy achievement at both the pre-instructional and post-instructional stages. Finally, the researchers discussed recommendations with the model teacher regarding the overall set of instructional materials developed.

The data collection technique employed in this study was testing; accordingly, the instrument used to collect data consisted of literacy and numeracy test sheets. The test items developed were multiple-choice questions measuring students' scientific literacy and numeracy, totaling 16 items. All measurements across the entire series of pre-tests and post-tests were conducted using the same research instrument. The item blueprint of the multiple-choice test (encompassing aspects, indicators, and item numbers) was developed based on a review of relevant theoretical literature on scientific literacy and numeracy (Firdaus & Asmali, 2021; OECD, 2019; Tim Substansi Asesmen Akademik et al., 2021). The competencies assessed in scientific literacy encompass three primary aspects, namely explaining phenomena scientifically, designing scientific investigations, and interpreting data and evidence scientifically. Meanwhile, numeracy was assessed across several aspects: mathematical processes for problem-solving, mathematical content, and mathematical context.

Instrument

Validity testing was conducted using both content validity and empirical validity. Content validity was established by requesting expert lecturers in scientific literacy and numeracy to provide judgment on the developed test items. The results of the expert judgment validation yielded a mean score of 3.58, categorized as Very Feasible. Furthermore, the validated multiple-choice test instrument, when reviewed in terms of content, obtained a mean score of 3.63, categorized as Very Feasible; in terms of construct, a mean score of 3.38, also categorized as Very Feasible; and in terms of language, a mean score of 3.75, likewise categorized as Very Feasible. The Pearson product-moment correlation was employed to test the empirical validity of each test item. An item is considered valid when r-calculated > r-table. Initially, 24 items encompassing scientific literacy and numeracy were developed. Following administration to 28 fifth-grade elementary school students who had received science learning material with sufficient relevance to climate change, the test instrument was found to be both valid and reliable. However, only 16 out of the 24 administered items yielded r-calculated > r-table (0.379). Reliability was tested using Cronbach's Alpha, with values of 0.60 < r-xy < 0.80 indicating High reliability and 0.80 < r-xy < 1.00 indicating Very High reliability. The reliability of the 16 valid items was subsequently assessed, yielding a coefficient of 0.728, indicating High reliability. The test items' discriminating power and difficulty level were also calculated and analyzed. With respect to discriminating power, 5 items demonstrated Moderate discriminating power, 7 items demonstrated High discriminating power, and 4 items demonstrated Very High discriminating power. Additionally, with respect to difficulty level, 5 items were categorized as Easy, 7 items as Moderate, and 1 item as Difficult.

Data Analysis

The data in this study were analyzed not only before and after the delivery of STEM instructional treatment to students, but also with respect to trends and stability in students' scientific literacy and numeracy achievement over time. Therefore, Segmented Regression Analysis was employed to analyze the data and examine, in greater detail, the developmental trends both prior to and following the treatment, as well as to capture both immediate changes and long-term trend shifts. In addition, the data were visualized using time-series graphs to observe patterns in students' scientific literacy and numeracy achievement.

FINDINGS

Prerequisite Test and Hypothesis Testing Results

This results and discussion section presents the learning progression of students' scientific literacy and numeracy following their engagement in STEM instructional facilitation. The data analysis indicates a progression in students' achievement both before and after the STEM instructional intervention. These findings are subsequently discussed in relation to relevant theoretical frameworks and prior empirical studies.

Table 1. One-Tailed Paired Sample T-Test Results

T-test: paired two-sample for means	Variable 1	Variable 2
Mean	6.895	8.5625
Variance	0.238767	0.357892
Observations	4	4
Pearson correlation	-0.81058	
Hypothesized mean difference	0	
df	3	
t stat	-3.22323	
p (t ≤ t) one-tail	0.024233	
The critical one-tailed	2.353363	
p (t ≤ t) two-tailed	0.048465	
The critical two-tailed	3.182446	

Prior to hypothesis testing, a prerequisite normality test was conducted to determine the appropriate subsequent analytical procedure. Based on the data normality test, the p-value from the Kolmogorov-Smirnov test was 0.200 > 0.05, indicating that the mean scores for students' scientific literacy and numeracy were normally distributed. Accordingly, the analysis proceeded with a one-tailed Paired Sample T-Test. The significance value is 0.024 < 0.05, indicating that students' scientific literacy and numeracy following STEM instruction improved significantly compared to before the intervention. The test results are presented in Table 1.

Interrupted Time Series (ITS) Analysis

The learning progression of students' scientific literacy and numeracy is the primary objective of this microgenetic study of STEM instruction. To examine more deeply how student progress during the learning process, an Interrupted Time Series (ITS) analysis was applied to students' data on scientific literacy and numeracy. Segmented Regression Analysis was employed to distinguish three critical points in development: the trend before, at the point of, and after the delivery of the intervention. Based on the results of the analysis, the following regression equation was obtained:

$$7.810 - 0.366 \text{ (Time)} + 1.164 \text{ (Intervention)} + 0.787 \text{ (Time After)}$$

As shown in Table 2, the intercept of 7.810 ($p < 0.001$) represents the baseline level of students' scientific literacy and numeracy prior to the delivery of STEM instruction. Time –0.366 ($p = 0.028$) indicates that students tended to experience a decline in their scientific literacy and numeracy of approximately 0.366 points per period before the intervention was administered. This pattern suggests that students' achievement was unstable in the absence of an intervention. Intervention +1.164 ($p = 0.032$) reveals an immediate level increase of 1.164 points in scores following the commencement of STEM instruction. This indicates that the implementation of STEM learning had a direct impact on students' achievement. Time After +0.787 ($p = 0.007$) indicates that the score trend changed significantly over the course of the intervention. This development suggests that STEM instruction did not merely produce a momentary effect but also contributed to a sustained upward improvement.

Table 2. Segmented Regression Analysis Result

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	7.810	0.296		26.366	0.000
	Time	-0.366	0.108	-0.875	-3.384	0.028
	Intervensi	1.164	0.359	0.607	3.245	0.032
	Time_After	0.787	0.153	1.214	5.145	0.007

This ITS analysis demonstrates that the STEM instructional intervention delivered to students had a significant positive effect on their scientific literacy and numeracy. The intervention reversed the previously declining developmental trend, immediately elevated the score, and directed it toward a positive trajectory in subsequent periods. The analysis continued with the visualization of students' developmental trajectories in scientific literacy and numeracy.

Developmental Trend of Students' Scientific Literacy and Numeracy

The trend analysis indicates that STEM instruction had a positive, significant impact on students' scientific literacy and numeracy. Prior to the intervention, scores showed a tendency to decline over time, suggesting that, in the absence of a targeted intervention, students' achievement was unstable and even declined. However, the trend revealed a progression in students' development following the intervention. This indicates that the STEM instruction delivered to students did not merely produce a momentary effect but also progressively developed students' scientific literacy and numeracy across subsequent periods.

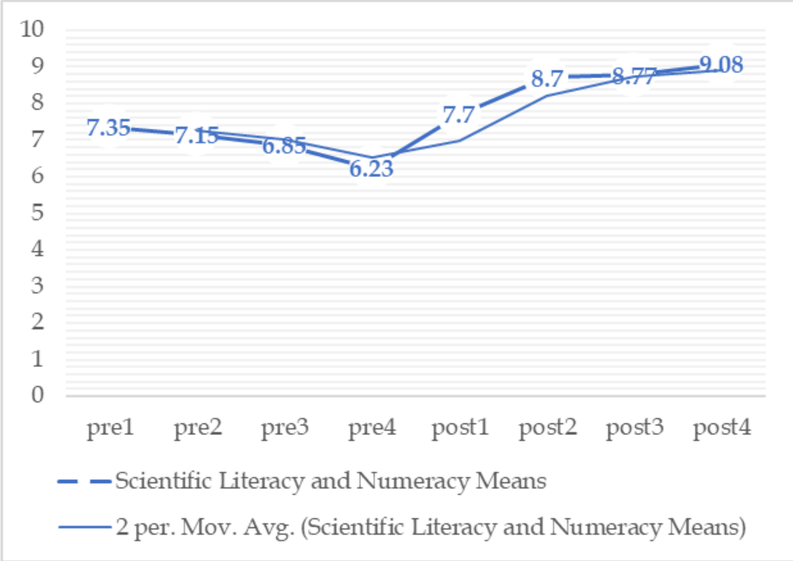

Figure 2. The Developmental Trend of Students' Scientific Literacy and Numeracy

STEM Instructional Process and Learning Activities

The key to the successful implementation of this study lies in applying STEM-based instruction that integrates scientific literacy and numeracy in the teaching of climate change content. The instructional process was conducted over two sessions: a conceptual learning session on climate change (as shown in Figure 3) and a STEM project-based learning session to apply the previously acquired concepts (as shown in Figure 4). In the first session, the implementation of climate change content learning focused on student activity through teacher-facilitated, collaborative group discussions. These activities represented an effort to strengthen scientific literacy and numeracy through discussion and by connecting scientific concepts to current phenomena, namely, climate change.

Figure 3. First Session Learning Activity

Figure 4. Second Session Learning Activity

Meanwhile, implementing STEM project-based learning required students to engage in active group work to complete project tasks. This activity required students to integrate their scientific literacy and numeracy, as well as collaborative skills, throughout the project. Ultimately, the series of STEM instructional activities delivered to students improved their scientific literacy and numeracy.

DISCUSSION

Prior to the delivery of the STEM instructional intervention, students' scientific literacy and numeracy were relatively low, as reflected in the baseline intercept of 7.810 and the declining pre-intervention trend of −0.366 points per period. This condition is consistent with findings at the national level, where the scientific literacy and numeracy of elementary school students in Indonesia have been reported to be low (Kamal et al., 2024), and with the persistent gap documented in Indonesia's PISA 2022 results across science and mathematics domains (OECD, 2023). The pre-intervention decline observed in this study suggests that, without targeted instructional intervention, students' achievement in these domains is not merely stagnant but actively regresses — a pattern that underscores the urgency of designing purposeful, contextually grounded instruction (Fitrianingrum & Murtiyasa, 2023). Low scientific literacy among students results in a generation not yet capable of optimally supporting the achievement of the SDGs (Trisanti et al., 2025), reinforcing the need to address this gap through integrated approaches such as STEM.

Low levels of scientific literacy and numeracy are influenced by interrelated factors related to instruction, learning resources, and student context. From an instructional standpoint, the learning process remains dominated by rote memorization, has yet to support scientific reasoning adequately, and leaves students unaccustomed to connecting scientific and mathematical concepts to real-world situations. Furthermore, the evaluation items have not been aligned with scientific literacy and numeracy indicators, particularly the discourse-based and real-world context items used in TIMSS and PISA. From a learning resources perspective, instructional materials and media are insufficiently contextualized, lack innovation, and are not digitally integrated, thereby limiting students' access to meaningful learning experiences. From the perspectives of students and teachers, low reading interest, difficulties comprehending symbols and scientific representations, and teachers' limited knowledge of scientific literacy and numeracy further compound the problem (Fitrianingrum & Murtiyasa, 2023; Kamal et al., 2024; Kasmawati et al., 2025; Nuryanti et al., 2023; A. P. Purnamasari et al., 2025; Siregar et al., 2025).

The learning progression observed in this study — characterized by an immediate score increase of +1.164 points at the onset of intervention and a sustained upward trend of +0.787 points per period thereafter — reveals that STEM instruction operates through two distinct mechanisms. The first is an *immediate activation effect*: the contextual, problem-based nature of STEM instruction in the first session, which focused on collaborative discussion of climate change phenomena, immediately activated students' prior knowledge and connected abstract scientific and mathematical concepts to lived experience. This aligns with the understanding that learning progression occurs when students connect prior ideas and experiences with new ones through coherently designed instructional materials (Fortus & Krajcik, 2012). The second is a *sustained development effect*: the project-based second session required students to apply and integrate both scientific literacy and numeracy across the full arc of a STEM project — from data collection and measurement to analysis and presentation — reinforcing conceptual understanding through practice over time. This two-phase mechanism explains why the ITS analysis reveals not merely a post-test improvement but a genuinely progressive developmental trajectory, consistent with the definition of learning progression as a map of students' cognitive changes as they engage with specific concepts over time (Anggoro et al., 2019).

These findings are consistent with prior studies asserting that STEM is effective in enhancing scientific literacy (Permatasari et al., 2024; Putri et al., 2024; Sulistina et al., 2024) and numeracy among elementary school students (Lustania et al., 2025; Nurwijaya, 2024). Scientific literacy is no longer understood merely as memorization of concepts. However, rather as the ability to assess the risks, impacts, and implications of science in relation to environmental and social issues, including climate change (A. P. Purnamasari et al., 2025) From a numeracy perspective, STEM instruction presents numerical concepts in concrete, applied forms — through data processing, measurement, and simple analysis within project activities — enabling students to comprehend and apply mathematical concepts more readily (Fitrianingrum & Murtiyasa, 2023; Susilana et al., 2024). This is consistent with the view that numeracy represents an essential competency for understanding contemporary scientific problems related to environmental issues and sustainable development (Chairunnisya et al., 2023).

What distinguishes this study from prior STEM research is its specific situatedness within SDG 13: Climate Action as an instructional context and its use of an Interrupted Time Series analytical framework to examine learning progression rather than merely pre-post differences. While previous studies have demonstrated STEM's general effectiveness in fostering scientific literacy or environmental awareness (Afkarina et al., 2024; Hartati & Hariyono, 2020), none have traced the developmental trajectories of both scientific literacy and numeracy simultaneously across repeated measurement points within a climate action context at the elementary school level. The ITS analysis employed in this study reveals that STEM instruction not only produces statistically significant improvement but generates a qualitatively distinct developmental pattern — one that reverses a pre-existing decline, produces an immediate level shift, and sustains a positive trajectory — which is precisely the signature of genuine learning progression as opposed to momentary performance gain. This finding contributes to the growing body of evidence supporting the integration of the SDGs into STEM instruction to develop both cognitive competencies and global citizenship awareness (Hartati & Hariyono, 2020; S. Purnamasari & Hanifah, 2021).

Furthermore, integrating STEM instruction into climate change content supports the principles of Education for Sustainable Development (ESD), which emphasize systems thinking, critical thinking, and problem-solving competencies (S. Purnamasari & Hanifah, 2021). The contextual grounding of instruction in SDG 13 means that students are not merely developing abstract literacy skills but are simultaneously building awareness of and readiness to respond to real global challenges — a dual outcome that aligns with ESD's vision of education as a transformative force for sustainable futures (Hartati & Hariyono, 2020). This study's findings thus carry implications beyond the classroom: schools that strategically integrate SDG content into STEM instruction may contribute more substantively to achieving SDG 13 targets by cultivating a generation of students who are both scientifically literate and environmentally aware.

Teachers need to develop a sound understanding of STEM instruction rather than perceiving it as an additional burden. More effective STEM integration focuses on developing students' thinking processes, inquiry skills, and problem-solving abilities rather than seeking content that merely overlaps across disciplines (Way et al., 2022). Teachers require adequate support to remain motivated in implementing STEM instruction, including collaboration with peers, high-quality curriculum materials, and effective professional development (Margot & Kettler, 2019).

This study is not without limitations. The use of a single-class sample from a single school limits the generalizability of the findings, as the results may not be representative of broader student populations across different socioeconomic, geographic, or instructional contexts. The relatively small number of measurement points (four pre-tests and four post-tests), while sufficient for ITS analysis, constrains the robustness of the trend estimates. Additionally, this study focused exclusively on cognitive outcomes — scientific literacy and numeracy — without examining non-cognitive dimensions such as scientific attitudes, environmental awareness, or collaborative skills, which may also be meaningfully influenced by STEM instruction in the context of climate action. Future research is encouraged to address these limitations by using larger, more diverse samples, extending time-series measurements, and including non-cognitive outcome variables within ESD and SDGs frameworks.

CONCLUSION

This study concludes that STEM instruction on SDG 13: Climate Action content significantly enhances elementary school students' scientific literacy and numeracy, as evidenced by a significance value of $0.024 < 0.05$ and an Interrupted Time Series analysis revealing a pre-intervention decline of −0.366 points per period, an immediate score increase of +1.164 points at the onset of intervention, and a sustained upward trend of +0.787 points per period thereafter — a developmental trajectory that reflects genuine learning progression rather than momentary performance gain. The novelty of this study lies in its simultaneous examination of both scientific literacy and numeracy development within STEM instruction specifically situated in SDG 13: Climate Action, analyzed through a learning progression lens using an ITS analytical framework at the elementary school level — an integration that, to the authors' knowledge, has not been previously reported in the literature. These findings have practical implications for teachers and curriculum developers seeking to embed SDG content into elementary science instruction, as the two-session STEM instructional design employed in this study — combining conceptual learning about climate change with project-based application — proved replicable and effective in standard school settings. Nonetheless, this study is limited by its single-class sample from one school, which constrains the generalizability of the findings; future research is therefore encouraged to employ larger and more diverse samples, extended time-series measurement points, and broader outcome variables, including non-cognitive dimensions such as environmental awareness and collaborative skills, particularly within the ESD and SDGs frameworks.

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