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Effectiveness of the PjBL-STEAM-IC model in improving students' environmental awareness in coastal schools

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Abstract: Coastal ecosystem degradation in Pagimana District, combined with science instruction that remains largely theoretical, underscores to the need for a learning model that can foster students' environmental awareness more comprehensively. This study examined the effectiveness of the PjBL-STEAM-IC model in improving students' environmental awareness in coastal schools across the four KABS dimensions: knowledge, attitude, behavior, and skills. The study was part of a Research and Development project and specifically reports the field-testing phase, which included limited trials, wider trials, and operational implementation. Participants were 150 seventh-grade students from four coastal junior high schools in Pagimana District. Data were collected using an environmental awareness questionnaire and analyzed using descriptive statistics, N-gain, the Wilcoxon Signed-Rank Test, and the Kruskal-Wallis Test. The results showed that the PjBL-STEAM-IC model effectively improved students' environmental awareness across all four dimensions. The mean score increased from 67.41 before implementation to 86.81 after implementation, with N-gain values ranging from 0.62 to 0.64, and all dimensions showed significant differences ($p < 0.001$). These findings suggest that the PjBL-STEAM-IC model is a promising contextual science learning alternative for strengthening environmental awareness in coastal schools.

Keywords: Coastal school, environmental awareness, science learning

Abstrak: Degradasi ekosistem pesisir di Kecamatan Pagimana, disertai pembelajaran IPA yang masih cenderung teoritis, menunjukkan perlunya model pembelajaran yang mampu membangun kesadaran lingkungan siswa secara lebih utuh. Penelitian ini bertujuan menganalisis efektivitas model PjBL-STEAM-IC dalam meningkatkan kesadaran lingkungan siswa sekolah pesisir berdasarkan empat dimensi KABS, yaitu pengetahuan, sikap, perilaku, dan keterampilan. Penelitian ini merupakan bagian dari penelitian dan pengembangan (*Research and Development*) dan pada artikel ini difokuskan pada tahap uji lapangan, yang meliputi uji coba terbatas, uji coba luas, dan implementasi operasional. Subjek penelitian berjumlah 150 siswa kelas VII dari empat SMP pesisir di Kecamatan Pagimana. Data dikumpulkan menggunakan kuesioner kesadaran lingkungan dan dianalisis dengan statistik deskriptif, N-gain, uji Wilcoxon, dan uji Kruskal-Wallis. Hasil penelitian menunjukkan bahwa model PjBL-STEAM-IC efektif meningkatkan kesadaran lingkungan siswa pada seluruh dimensi KABS. Skor rata-rata meningkat dari 67,41 sebelum implementasi menjadi 86,81 sesudah implementasi, dengan nilai N-gain berkisar 0,62–0,64 dan seluruh dimensi menunjukkan perbedaan yang signifikan ($p < 0{,}001$). Temuan ini menunjukkan bahwa model PjBL-STEAM-IC layak dipertimbangkan sebagai alternatif pembelajaran IPA yang kontekstual untuk memperkuat kesadaran lingkungan siswa di sekolah pesisir.

Kata kunci: Sekolah pesisir, kesadaran lingkungan, pembelajaran sains

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INTRODUCTION

Coastal ecosystems are living spaces that support biodiversity, protect shorelines, and sustain local communities. In Pagimana District, Banggai Regency, pressure on coastal ecosystems remains substantial, especially in mangrove areas and coastal habitats. Mangrove degradation in this region not only reduces habitat quality but also affects fishers' catches and the overall balance of coastal ecosystems (Badjeber et al., 2020). The problem is also closely tied to how coastal communities interact with local resources and to the difficulty of translating ecological knowledge into everyday conservation practices (Loch & Riechers, 2021). In this context, schools have a strategic role because environmental education cannot stop at knowledge alone; it must extend to awareness and action.

The challenge is that science learning in coastal schools remains largely theoretical and has not yet fully used local environmental issues as meaningful learning contexts. Students may recognize ecological concepts, yet they do not necessarily demonstrate consistent attitudes, behaviors, and skills in caring for the environment. This condition reflects the environmental knowledge-action gap, namely the gap between knowledge about the environment and actual pro-environmental behavior. In coastal communities, rich local ecological knowledge does not always develop into consistent conservation practices unless it is reinforced through relevant learning experiences (Loch & Riechers, 2021; Samputri & Safitri, 2020). In educational research, the gap between environmental values, knowledge, and action also remains an unresolved concern (Gifford & Nilsson, 2014; Portus et al., 2024).

A number of studies have shown that project-based and contextual learning can strengthen science learning and environmental education. Nusantari et al. (2020) found that environmentally based science learning effectively supported environmentally friendly character among students in coastal areas, while Asri et al. (2020) highlighted the importance of learning models that connect environmental problems with students' lived experiences. At the same time, environmental awareness is understood as a multidimensional construct that includes knowledge, attitudes, behavior, and skills, so its development needs to be designed in an integrated way (McBeth & Volk, 2009; Perea et al., 2025; Spínola, 2023). Environmental awareness has even been viewed as a crucial basis for protecting nature and sustaining human life (Pramita et al., 2023).

Even so, the implementation of PjBL and STEAM is not without limitations. PjBL encourages student engagement with authentic problems and collaborative work (Bell, 2010; Blumenfeld et al., 1991; Rahman et al., 2019), while STEAM supports interdisciplinary integration. However, several studies show that STEAM implementation still tends to emphasize technical and product-oriented aspects, whereas the epistemic connections among its components are not always built in a coherent way (Antunes & Trigo, 2024; Quigley et al., 2017; Singh et al., 2024). In addition, studies on PjBL-STEAM indicate that more substantive dimensions of creativity, such as originality and elaboration, do not always develop optimally when innovation is not explicitly operationalized in the learning syntax (Ariyani et al., 2025; Fitriani et al., 2025). In other words, PjBL-STEAM is promising, but it is not always strong enough to build deep, contextual, and sustainable environmental awareness.

Against this background, the PjBL-STEAM-IC model was developed by integrating Project-Based Learning, Science, Technology, Engineering, Art, Mathematics, as well as Innovation and Creativity into its learning syntax. In the previous development stage, the model underwent theoretical and content validation and was refined through staged field trials before being tested for effectiveness (Nieveen, 1999; Plomp & Nieveen, 2013). The next important step was to examine whether the model was truly effective when implemented in actual learning situations in coastal schools. Therefore, this article aimed to analyze the effectiveness of the PjBL-STEAM-IC model in improving students' environmental awareness across the four KABS dimensions: knowledge, attitude, behavior, and skills.

METHOD

Research design

This study was part of a Research and Development (R&D) project on the PjBL-STEAM-IC model, adapted from Borg and Gall (Sugiyono, 2015). In the broader study, the development process included a preliminary study, hypothetical model design, the development of instructional tools and instruments, expert validation, limited trials, wider trials, and operational implementation. This article does not discuss the entire development process; instead, it specifically focuses on the effectiveness of the model during the staged field-testing phase. Accordingly, the data analyzed in this article were drawn from three phases of field testing limited trials, wider trials, and operational implementation which were treated as sequential stages within educational development research rather than as three independent studies.

To assess changes in students' environmental awareness after implementation of the model, the study used a one-group before-and-after implementation design at each field-testing stage. This design was chosen because the primary aim of the article was to examine changes in students' environmental awareness scores before and after implementation of the PjBL-STEAM-IC model in coastal school contexts. The effectiveness focus in this article was limited to four dimensions of environmental awareness: knowledge, attitude, behavior, and skills.

Participants

The study was conducted during the second semester of the 2024/2025 academic year in four coastal junior high schools in Pagimana District, Banggai Regency, Central Sulawesi, namely SMP Negeri 1 Pagimana, SMP Negeri 3 Pagimana, SMP Negeri 10 Pagimana, and SMP Islam Pagimana. These schools were selected purposively because they represent coastal school contexts that are relevant to coastal ecosystem content and to the objectives of the model development. The full study involved 150 seventh-grade students.

The distribution of participants followed the stages of field testing in the development study. The limited trial involved 30 students from SMP Negeri 1 Pagimana. The wider trial involved 60 students from two parallel classes at SMP Negeri 3 Pagimana. The operational implementation involved 60 students from SMP Negeri 10 Pagimana and SMP Islam Pagimana. This staged arrangement was intended to examine the model's performance from early implementation to a more mature operational stage. The study was conducted with permission from the participating schools.

Instrument

The main instrument used in this study was an environmental awareness questionnaire designed to measure changes in students' environmental awareness before and after the implementation of the PjBL-STEAM-IC model. The questionnaire consisted of 24 statements distributed equally across four KABS dimensions: environmental knowledge, environmental attitude, environmental behavior, and environmental skills, with six statements representing each dimension. The questionnaire was administered twice, namely before implementation as the initial measurement and after implementation as the final measurement. Scores were calculated both overall and by dimension to examine patterns of change in students' environmental awareness.

Prior to its use in the field-testing phase, the environmental awareness questionnaire was validated by three expert validators. The validation assessed the representation of the four KABS dimensions, relevance to coastal environmental contexts, content appropriateness, item construction, language, technical quality, ethical considerations, analytical suitability, and overall feasibility. The validation results showed an overall Aiken's V coefficient of 0.948 and an overall validity percentage of 96.11%, indicating that the questionnaire was highly valid. The reliability of expert judgments reached R = 0.844, indicating a high level of consistency among validators. Based on these results, the questionnaire was considered appropriate for measuring students' environmental awareness in coastal school contexts.

Data Analysis

The data were analyzed quantitatively. Descriptive statistics were used to describe scores before and after implementation, both overall and for each KABS dimension. The magnitude of score improvement was calculated using N-gain with (Hake, 1998) interpretive categories. N-gain was used to show the degree of score improvement more clearly after implementation of the model.

To test the significance of differences between scores before and after implementation, the Wilcoxon Signed-Rank Test was used. This test was selected because the data consisted of paired scores collected before and after treatment, and the effectiveness analysis in this development study was directed toward a nonparametric approach. To examine whether the degree of improvement differed across schools, the Kruskal-Wallis test was applied to the N-gain scores. The analysis was also complemented by effect size so that the practical meaning of score improvement could be interpreted more clearly, not merely in terms of statistical significance.

In this article, the model was considered effective when it met three main indicators: (1) scores after implementation were higher than scores before implementation, (2) the difference between them was statistically significant, and (3) the N-gain values showed at least a moderate increase in most environmental awareness dimensions. In this way, the model's effectiveness was interpreted not only in terms of whether score differences existed, but also in terms of how substantial the improvement was after learning.

RESULTS AND DISCUSSION

This study examined the effectiveness of the PjBL-STEAM-IC model during the staged field-testing phase, which included limited trials, wider trials, and operational implementation. The analysis focused on changes in students' environmental awareness after instruction, as measured through the four KABS dimensions: knowledge, attitude, behavior, and environmental skills. Overall, the findings show that implementation of the model in coastal schools was followed by increased scores across all measured dimensions.

As shown in Table 1, students' mean environmental awareness scores increased across all dimensions after implementation of the model. Scores before implementation ranged from 65.58 to 68.69, whereas scores after implementation increased to 85.07–87.54. N-gain values ranged from 0.62 to 0.64, and all dimensions showed large effect sizes. The Wilcoxon test also showed that the differences between scores before and after implementation were significant across all dimensions ($p < 0.001$). These findings indicate that the observed improvement was not only descriptively visible, but also statistically meaningful.

Table 1. Descriptive statistics of students' environmental awareness across the four dimensions

Dimension	**Before impl.**	**After impl.**	**N-gain**	**N-gain category**	**Effect size**	**Effect size category**	**p-value**
Environmental knowledge	68.18	87.54	0.64	Moderate	0.95	Large	<0.001
Environmental attitude	68.69	87.42	0.63	Moderate	0.95	Large	<0.001
Environmental behavior	65.58	85.07	0.62	Moderate	0.98	Large	<0.001
Environmental skills	67.18	87.22	0.64	Moderate	0.95	Large	<0.001
Overall mean	67.41	86.81	0.63	Moderate	0.96	Large	<0.001

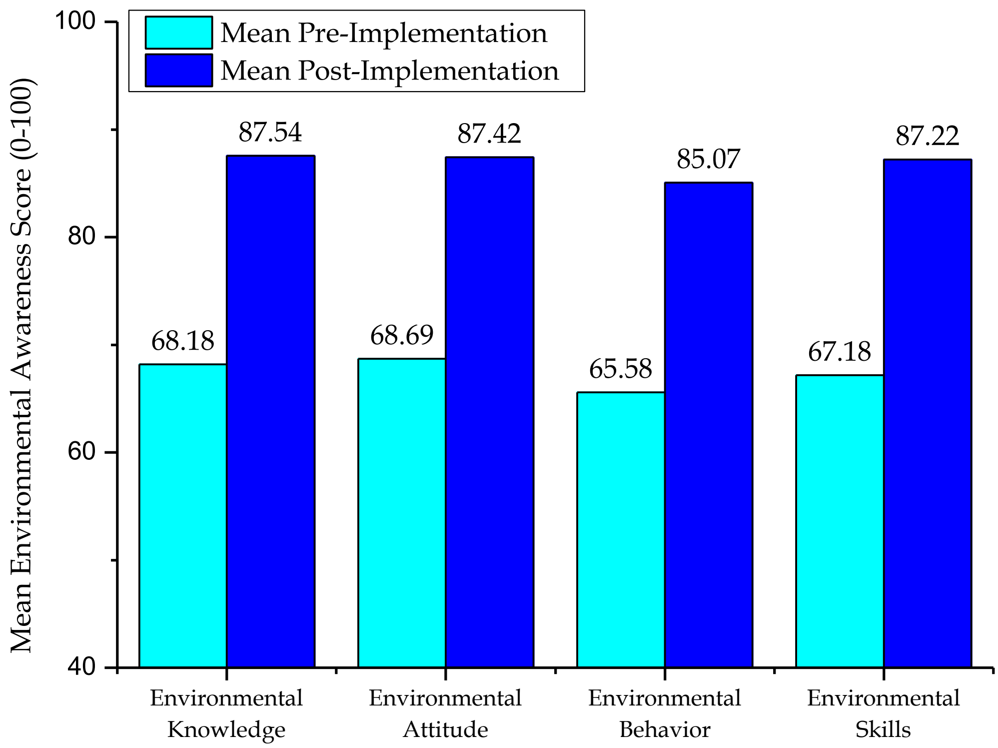

Fig. 1. Comparison of mean environmental awareness scores before and after implementation across the four dimensions

The upward trend in scores before and after implementation across all four dimensions is also shown in Figure 1. Visually, all dimensions display the same general pattern, moving from lower initial scores to higher final scores. The most pronounced gains appear in environmental knowledge and environmental skills, although the attitude and behavior dimensions also show strong positive trends.

To determine whether the improvement varied across schools, the Kruskal-Wallis test was applied to the N-gain scores. The results are presented in Table 2. Only the environmental knowledge dimension showed a significant difference across schools (p = 0.000), whereas environmental attitude, behavior, and skills did not differ significantly. Thus, variation across schools appeared mainly in the knowledge dimension, while the other three dimensions showed a more stable pattern of improvement across school contexts.

Table 2. Kruskal-Wallis test results for N-gain in environmental awareness across schools

Dimension	H	df	p-value	Interpretation
Environmental knowledge	21.031	4	0.000	Significant
Environmental attitude	3.705	4	0.447	Not significant
Environmental behavior	3.492	4	0.479	Not significant
Environmental skills	9.362	4	0.053	Not significant

Overall, the results show that the PjBL-STEAM-IC model was effective in improving students' environmental awareness in coastal schools. Its effectiveness is reflected in higher scores after implementation, moderate N-gain values, large effect sizes, and significant differences between conditions before and after implementation across all KABS dimensions.

The findings show that the PjBL-STEAM-IC model did not merely improve environmental awareness in a general sense; it produced simultaneous changes in environmental knowledge, attitude, behavior, and skills. This is important because environmental awareness in coastal education cannot be reduced to ecological knowledge alone. It also includes how students understand environmental problems, judge their importance, show tendencies toward more responsible behavior, and develop skills for responding to environmental problems in practical ways (McBeth & Volk, 2009; Perea et al., 2025; Stern, 2000). In that sense, improvement across all four KABS dimensions suggests that the model worked in a comprehensive way rather than affecting only one side of learning outcomes.

Environmental knowledge and environmental skills emerged as the two most responsive dimensions. This finding is reasonable because the PjBL-STEAM-IC syntax places students in activities that directly demand both, such as observing coastal environmental problems, collecting and interpreting information, designing project plans, and presenting results. In such learning situations, knowledge develops not as memorized information but as understanding used to explain problems and weigh solutions. At the same time, environmental skills improve because students do not merely talk about problems; they work through procedures that require observation, information organization, product development, and communication of results. This interpretation is consistent with Frick et al. (2004) on environmental knowledge and is reinforced by

Salsabila et al. (2019), Rahmawati et al. (2021), and Ridwan et al. (2020), all of whom found that inquiry-oriented and STEAM-integrated learning can strengthen students' thinking abilities and action-related skills, even though those studies did not specifically focus on the four dimensions of environmental awareness.

Environmental attitudes also shifted in a positive direction. This indicates that project-based learning experiences went beyond academic tasks and influenced how students viewed coastal problems and the importance of caring for the environment. Within this model, students were not simply given explanations about coastal degradation; they confronted problems that were close to their own lives, discussed their consequences, and reflected on the meaning of the actions they took during learning. For that reason, the attitudinal change observed in this study is better understood as the result of involvement and reflection rather than as a product of information delivery alone. This interpretation aligns with Schultz et al. (2004) on environmental attitudes and with Steg (2016) on the role of values and intrinsic motivation in pro-environmental action.

The behavior dimension also showed a significant increase. Still, this finding should be interpreted proportionally. The increase indicates that the model succeeded in initiating a meaningful shift toward pro-environmental behavior, but it should not yet be interpreted as evidence of fully established and stable habits. The implementation in this study lasted only three project-based meetings, so the safest conclusion is that the model shifted students' tendencies toward more positive behavior. For such change to become stable, it still requires repetition, a consistent school culture, and support from the broader social environment. This explanation is consistent with the environmental knowledge-action gap and with the range of personal and social factors that shape pro-environmental behavior (Gifford & Nilsson, 2014; Portus et al., 2024). In coastal contexts, Samputri & Safitri (2020) showed that environmental knowledge does not automatically produce environmentally friendly behavior, while Loch & Riechers (2021) argued that local ecological knowledge does not necessarily translate into consistent conservation practice.

Variation across schools also yielded an important finding. Only the environmental knowledge dimension differed significantly across schools, whereas attitude, behavior, and skills did not. This suggests that the strengthening of environmental knowledge is more sensitive to implementation quality. When the syntax is enacted more consistently, the instructional tools are more mature, and teacher facilitation is more stable, knowledge gains tend to be stronger. In contrast, the attitude, behavior, and skills dimensions appear more evenly distributed across schools. This pattern suggests that coastal project experiences have a relatively stable formative effect on the affective and performative domains, even though the most intense gains still appear in more mature stages of implementation. Within the logic of educational development research, such a pattern is expected because product quality increases through iterative revision and implementation refinement (Nieveen, 1999; Plomp & Nieveen, 2013).

From a pedagogical standpoint, the model's effectiveness in building environmental awareness can be explained through the combination of project work, direct experience, presentation, data analysis, and reflection. When students confront coastal issues that are close to their lives, learning becomes more meaningful because the problems studied are not distant or abstract. Project work gives students room to act rather than merely listen. Presentation and data analysis help them understand relationships among causes, consequences, and possible solutions. Reflection helps them reconsider their own position in relation to the environment they are studying. In this arrangement, environmental awareness grows through a sequence of learning experiences that allows students to understand, feel, try, and then evaluate the meaning of their own actions. This mechanism is consistent with the core character of PjBL, which places authentic problems, investigation, and products at the center of the learning experience (Bell, 2010; Blumenfeld et al., 1991; Rahman et al., 2019).

These findings also highlight the strength of the PjBL-STEAM-IC model as a contextual science learning model for coastal schools. Its central value lies in its ability to connect local environmental issues with project-based learning, operationalize STEAM-IC components, and target environmental awareness in a multidimensional way. In this sense, the model is not only relevant for helping students understand science concepts; it also has the potential to build a stronger ecological orientation through authentic and reflective learning experiences. Unlike Asri et al. (2020), who focused more on improving environmental knowledge through documentary media in coastal communities, the present study shows simultaneous gains in environmental knowledge, attitude, behavior, and skills among junior high school students. The present findings also extend the work of Nusantari et al. (2020), who emphasized environmentally friendly character among coastal students, by showing that the PjBL-STEAM-IC model can improve all four KABS dimensions at once. On the other hand, several previous PjBL-STEAM studies have emphasized creativity, communication, critical thinking, or interdisciplinary integration (Ariyani et al., 2025; Fitriani et al., 2025; Quigley et al., 2017; Rahmawati et al., 2021; Ridwan et al., 2020), whereas the primary outcome in this study appears in the form of multidimensional environmental awareness.

Even so, this study still has limitations. It was conducted in coastal schools in Pagimana District and involved only seventh-grade students, so generalization to non-coastal contexts or other grade levels should be made cautiously. In addition, the relatively short implementation period means that the behavior dimension is better interpreted as an early but meaningful shift rather than as evidence of stabilized habits. Future studies should therefore examine the sustainability of environmental behavioral change over a longer period and in more varied school contexts.

CONCLUSION

This study shows that the PjBL-STEAM-IC model was effective in improving environmental awareness among students in coastal schools. The model's effectiveness is reflected in significant gains across the four KABS dimensions—knowledge, attitude, behavior, and environmental skills. Descriptively, the mean environmental awareness score increased from 67.41 before implementation to 86.81 after implementation, with N-gain values ranging from 0.62 to 0.64 and large effect sizes across all dimensions. These findings indicate that the model not only strengthened students' ecological understanding, but also supported the development of more positive attitudes, more responsible behavior, and more relevant environmental skills in coastal life contexts. Accordingly, the PjBL-STEAM-IC model can be recommended as a contextual science learning alternative for coastal schools seeking to strengthen students' environmental awareness in a multidimensional way. The model may also be considered by schools with similar characteristics that seek to connect local environmental issues with project-based learning in more meaningful ways.

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