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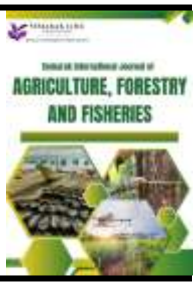

Fostering Sustainable Habits: Integrating Project-Based Learning and Mangrove Conservation for Environmental Education

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ABSTRACT

Sustainability education is crucial for cultivating environmental awareness, yet traditional classroom methods often lack practical engagement for real-world impact. Project-Based Learning (PBL) provides a hands-on approach by actively involving students in environmental conservation efforts, fostering experiential learning and long-term behavioural change. This study explores the integration of PBL into higher education through a mangrove conservation initiative, aligning with Sustainable Development Goals (SDGs) 4, 11, 13 and 14. Mangrove deforestation remains a critical global issue, with over 5,245 km² lost since 1996. Despite various conservation initiatives, community engagement and long-term participation remain low, primarily due to insufficient awareness and direct involvement. Conventional educational approaches often struggle to instil active participation and environmental responsibility, emphasizing the need for immersive, field-based learning experiences. This research evaluates PBL's effectiveness in sustainability education by incorporating mangrove conservation into university coursework through river cleanups, waste analysis, and community collaboration. The study employs a mixed-methods approach, integrating pre- and post-surveys, field observations, and impact assessment metrics to evaluate students' learning outcomes, behavioural intent, and environmental impact. Preliminary findings indicate a 45% increase in sustainability awareness, with 60% of participants committing to ongoing conservation activities. Additionally, waste analysis from cleanup efforts provides tangible insights into pollution patterns and the need for stronger waste management policies. The study underscores PBL's potential as an innovative educational strategy, promoting active learning, problem-solving, and environmental stewardship while bridging the gap between academic knowledge and real-world application.

1. Introduction

The relationship between humans and nature has always been deeply intertwined, yet in recent decades, rapid urbanization, industrial expansion and unsustainable consumption patterns have

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distanced people from their environmental responsibilities. While climate change, pollution and biodiversity loss dominate global discussions, the response from younger generations often lacks direct action or long-term engagement [1]. Despite increased awareness through media and educational initiatives, many students remain disconnected from the urgency of environmental conservation. This gap between knowledge and responsibility highlights the need for transformative educational approaches that instill sustainability consciousness through direct action and engagement. Education plays a pivotal role in shaping perspectives, behaviors and values. However, traditional classroom-based teaching methods often fail to inspire a sense of urgency or personal commitment to sustainability. While students may learn about deforestation, pollution and conservation, they rarely experience the real-world consequences of environmental degradation firsthand. In STEM and technical subjects, prolonged lecture-based, passive learning models further contribute to student disengagement, decreased motivation and limited retention. Long hours of passive note-taking and theoretical instruction leave students struggling to connect knowledge to practical applications, which is essential in fostering critical thinking and long-term engagement in sustainability efforts [2].

This is where Project-Based Learning (PBL) emerges as a powerful pedagogical tool, bridging theoretical learning with hands-on environmental action. Unlike traditional methods, PBL actively engages students in real-world projects, fostering problem-solving skills, critical thinking, and long-term environmental responsibility. Through multidisciplinary, experience-driven approaches, students develop a deeper connection to nature, enhance their analytical capabilities and contribute meaningfully to sustainability initiatives. In line with this philosophy, the MyBlueForest Project, under the Faculty of Information Science & Engineering's (FISE) Knowledge Transfer Partnership (KTP) initiative at Management and Science University (MSU), serves as an innovative platform for integrating PBL into sustainability education. This initiative aligns with Sustainable Development Goal 11 (Sustainable Cities and Communities) and Sustainable Development Goal 13 (Climate Action), reinforcing MSU's commitment to environmental sustainability as one of its 11 key research priorities. Through a multidisciplinary approach, the project promotes hands-on participation in conservation efforts including river cleanups, mangrove conservation awareness campaigns, and community engagement programs while ensuring that sustainability principles are embedded within academic coursework. By integrating sustainability into subject curricula, particularly System Analysis and Modelling, the initiative fosters a lifelong environmental mindset in students. This approach bridges classroom learning with real-world application, equipping students with the knowledge, skills, and ethical framework needed to address pressing environmental challenges and contribute actively to sustainable community development [3].

This study investigates the effectiveness of PBL in fostering sustainability awareness and responsibility among university students by evaluating MSU-led environmental conservation activities. It focuses on a river cleaning initiative conducted in September 2024, where students actively removed waste, analyzed pollution sources and engaged with local stakeholders. By placing students at the center of sustainability initiatives, this research seeks to analyze the impact of PBL on student engagement, focus and learning motivation in higher education; evaluate how hands-on environmental projects influence student awareness, participation and long-term commitment to sustainability; and assess how field-based experiential learning improves students' analytical thinking, problem-solving and system design application beyond traditional classroom learning. Figure 1 illustrates students' participation in river cleaning activities as part of the final project assessment.

Fig. 1. Students Participation for final project assessment

Note: Students work in groups for the river cleaning activity

This research ultimately explores how universities can incorporate experiential learning models to develop a generation of environmentally responsible citizens while enhancing student learning outcomes in technical and sustainability-focused disciplines.

1. Literature Review

1.1 Project-Based Learning (PBL) and Experiential Learning in Education

PBL has emerged as a transformative pedagogical approach, emphasizing active learning, real-world problem-solving and student-driven inquiry. Unlike traditional lecture-based learning, which often relies on passive knowledge transmission, PBL engages students through hands-on, collaborative projects that encourage deeper understanding, critical thinking and knowledge application [4]. Research has consistently shown that students who engage in PBL demonstrate improved problem-solving skills, higher motivation and greater knowledge retention compared to those in traditional classroom settings [5]. Experiential learning, which underpins PBL, is rooted in Kolb's Experiential Learning Theory (1984), which asserts that learning is most effective when students experience, reflect on, conceptualize and apply new knowledge. In technical fields, such as engineering, environmental sciences and system analysis, PBL enables students to connect theoretical knowledge with real-world applications [6]. Faba *et al.,* [7] found that students exposed to active learning methods, including PBL, outperformed their peers in traditional learning environments in both comprehension and long-term retention.

In sustainability education, PBL plays a critical role in bridging the gap between knowledge and action. While classroom instruction may introduce students to environmental issues, it often fails to instil a sense of responsibility and engagement in real-world sustainability efforts. Research suggests that learning through direct action such as conservation projects, community engagement and field-based experiences enhances students' environmental awareness and their commitment to sustainable practices [8]. The integration of sustainability-focused PBL in higher education curricula is gaining recognition as an effective means of developing environmentally responsible graduates. Table 1 presents the comparison between traditional and PBL showing how PBL enhances engagement, critical thinking and real-world application.

Table 1
Traditional *vs.* PBL-Based learning – A comparative analysis

Aspect	Traditional learning	Project-based learning
Student Engagement	Passive (lecture-based)	Active (hands-on, real-world projects)
Knowledge Retention	Lower due to memorization	Higher due to practical application
Problem- Solving Skills	Theoretical understanding	Applied learning through real-world problem-solving
Collaboration & Teamwork	Limited to group discussions	Emphasized through real-world projects
Critical Thinking	Minimal opportunities	Encourages analytical and decision-making skills
Long-Term Learning Impact Retention	Short-lived knowledge	Deeper, more impactful learning

1.2 The Role of Environmental Education in Higher Learning Institutions

Higher education institutions play a vital role in promoting environmental sustainability through education, research and community engagement. Universities are not only responsible for educating future professionals but also for fostering a culture of sustainability that extends beyond the classroom [9,10]. Sustainability education in higher institutions is often structured around the United Nations Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action), which emphasize education as a tool for promoting sustainable urban development and addressing climate change. Environmental education in universities traditionally focuses on policy discussions, theoretical models, and sustainability frameworks, but recent studies suggest that experiential learning provides a more effective approach to sustainability education. Research by Bramwell *et al.,* [11] found that students who engage in hands-on sustainability initiatives demonstrate a greater sense of personal agency and a stronger commitment to implementing sustainable practices.

The inclusion of PBL-based sustainability education ensures that students not only learn about environmental issues but actively participate in conservation efforts through projects such as waste management initiatives, mangrove restoration and urban sustainability planning. The MyBlueForest Project at MSU exemplifies how universities can integrate PBL into sustainability-focused curricula. By involving students in real-world conservation initiatives, such as river cleanups and mangrove preservation programs, MSU fosters an active learning environment where students connect academic knowledge to environmental action. The integration of sustainability into academic courses, particularly System Analysis and Modelling, demonstrates how technical education can be enriched by experiential learning opportunities. This approach aligns with research advocating for interdisciplinary collaboration in sustainability education, emphasizing the importance of practical engagement in fostering environmental responsibility [12].

1.3 Challenges in Mangrove Conservation and Community Engagement

Mangrove forests play a crucial role in coastal protection, carbon sequestration, and biodiversity conservation, yet they are among the most threatened ecosystems globally. Since 1996, over 5,245 km^2 of mangrove forests have been lost due to deforestation, urban expansion, and climate change [13]. Despite growing awareness of the importance of mangroves, conservation efforts often face significant challenges, particularly in community engagement and long-term sustainability. One of the primary obstacles to effective mangrove conservation is the lack of local community involvement. Research suggests that many conservation initiatives fail due to insufficient engagement with local stakeholders [14]. While policy-driven conservation strategies may provide short-term protection, sustainable conservation requires active participation from local communities, students and environmental organizations. Ditmar *et al.,* [15] argue that community-based conservation efforts are more likely to succeed when local populations are directly involved in planning, decision-making, and implementation.

Education plays a crucial role in bridging the gap between conservation initiatives and community participation. Studies have shown that educational programs that incorporate field-based conservation projects help cultivate a sense of environmental stewardship among students and community members [16]. The MyBlueForest Project addresses this issue by involving students in mangrove conservation awareness campaigns, river cleanups, and waste management initiatives. By incorporating PBL into sustainability education, the project ensures that students are not just passive learners but active participants in conservation efforts. Another challenge in mangrove conservation is the complexity of balancing environmental protection with economic development. In many coastal regions, mangroves are cleared for urban expansion, shrimp farming, and tourism, leading to conflicts between economic growth and ecosystem preservation [17]. This highlights the need for an integrated conservation approach that includes education, policy intervention, and community-driven action. Hemingson and Bellwood [18] emphasize that effective sustainability solutions require interdisciplinary collaboration, bringing together scientists, policymakers, educators and local stakeholders.

Through initiatives like the MyBlueForest Project at MSU, higher education institutions can play a pivotal role in addressing these challenges. By equipping students with knowledge, skills and direct engagement in conservation activities, universities can cultivate a new generation of environmentally conscious leaders who are prepared to tackle the pressing environmental challenges of the 21st century. In summary, the literature suggests that PBL is a highly effective pedagogical strategy for fostering sustainability education. The integration of experiential learning into higher education curricula provides students with real-world exposure to environmental challenges, helping them develop a sense of ownership and responsibility [19]. However, successful implementation requires institutional support, interdisciplinary collaboration, and active community engagement. This study builds upon existing research by evaluating the impact of PBL in System Analysis and Modelling, particularly how hands-on environmental projects influence student engagement, learning outcomes and long-term commitment to sustainability. Table 2 presents several case studies demonstrating the successful application of PBL in environmental contexts.

Table 2
Traditional *vs.* PBL-Based learning – A comparative analysis

Study/Initiative	Description	Outcome
Environmental Education Course Utilizing PBL	Undergraduate prospective elementary education students participated in an environmental education course employing PBL methodologies. Data were collected through end-of semester surveys with open-ended questions.	PBL created an active learning environment, enhancing students' environmental awareness and engagement.
Bahrain Teachers College Case Study	Research at Bahrain Teachers College explored the role of PBL in promoting environmental stewardship.	Integrating PBL into the curriculum increased students' environmental knowledge and empowered them to engage in conservation efforts.
Environmental Engineering PBL Case Study	An investigation into the application of PBL in an environmental engineering course assessed students' perceptions and attitudes.	Students found the PBL approach favourable, connecting theoretical concepts to real-world environmental challenges and enhancing problem-solving skills.
The Fairchild Challenge	A multidisciplinary environmental science competition engaging students from pre-K through 12th grade in exploring the natural world through PBL.	Participants undertook projects developing sustainability initiatives, fostering a deep connection to environmental issues and promoting active problem-solving skills.

These examples underscore that PBL is not a novel concept but a well-established and effective method in project-based classes, particularly within environmental education. The hands-on, experiential nature of PBL enables students to apply theoretical knowledge to real-world situations, thereby enhancing learning outcomes and fostering a sense of environmental responsibility.

2. Methodology

2.1 Research Design

This study employs a quasi-experimental research design to assess the impact of PBL compared to traditional classroom-based learning in higher education [20]. A mixed-methods approach was applied, integrating quantitative experimental data with qualitative insights to provide a comprehensive evaluation of student learning, engagement and knowledge retention. The study focuses on comparing two instructional approaches within the System Analysis and Modelling course at MSU. The quasi-experimental approach was selected due to the inability to randomly assign students to learning groups in an academic setting. Instead, the study utilized naturally occurring student groups enrolled in the course and assessed their learning outcomes based on instructional methodology [21]. The research followed a pre-test and post-test design, enabling measurement of knowledge acquisition, engagement levels and sustainability awareness before and after exposure to different teaching methods. Students were divided into two distinct groups:

i. Traditional Learning Group: Engaged in structured classroom-based group assignments, including case studies and theoretical problem-solving.
ii. PBL Learning Group: Participated in a sustainability-driven final project, applying theoretical knowledge to real-world environmental conservation projects.

To ensure scientific rigor, a combination of controlled assessments, structured surveys, and sustainability impact evaluations were conducted to quantify learning effectiveness. The primary research variables included knowledge retention (measured via pre-test and post-test scores), student engagement levels (assessed through Likert-scale surveys), and real-world sustainability contributions (quantified through field-based project data).

2.2 Sample Design

The study was conducted within the FISE at MSU, targeting undergraduate students enrolled in the System Analysis and Modelling course. A purposive sampling technique was used to ensure that participants had similar academic backgrounds and no prior exposure to PBL-based sustainability education. The study involved a total of 150 students, divided equally into:

i. Traditional Learning Group (n = 75): Students assigned to classroom-based theoretical group work using structured assignments.
ii. PBL Learning Group (n = 75): Students engaged in an applied sustainability project, integrating environmental conservation efforts.

The study spanned 12 weeks, following a structured experimental timeline:

i. Weeks 1-2: Baseline data collection (Pre-Test & Engagement Survey).
ii. Weeks 3-6: Traditional Learning Group completed theoretical assignments.
iii. Weeks 7-10: PBL Group participated in sustainability-driven projects (River Cleanup & Mangrove Conservation).
iv. Weeks 11-12: Post-Test, Engagement Survey and Sustainability Impact Assessment.

This sampling approach ensured that all participants experienced a controlled academic environment, allowing for a valid comparison between traditional learning methods and PBL-based sustainability education.

2.3 Analysis Design

A multi-dimensional analysis framework was applied to evaluate the effectiveness of PBL versus traditional learning. The study incorporated both quantitative and qualitative techniques, ensuring a scientifically sound comparison across multiple learning dimensions.

2.3.1 Pre-test and post-test knowledge assessment

The effectiveness of learning was measured through pre-test and post-test evaluations. These assessments contained 20 multiple-choice and applied system modeling questions, designed to measure knowledge acquisition and retention. A paired t-test was conducted to analyze statistically significant differences in student performance before and after instructional exposure.

2.3.2 Engagement and learning motivation survey

Student engagement and motivation levels were measured using a Likert-scale survey administered at the beginning and end of the study. The survey assessed factors such as active participation, interest in sustainability and problem-solving confidence. Responses were analyzed using ANOVA and descriptive statistics to compare engagement shifts between groups.

2.3.3 Sustainability impact metrics

The real-world impact of the PBL-based learning approach was further analyzed using sustainability performance indicators, measuring:

i. Waste reduction in the river cleanup project, quantifying the amount of plastic and non-biodegradable waste collected.
ii. Community engagement levels in the mangrove conservation awareness campaign, evaluating the effectiveness of student outreach efforts.
iii. Correlation between student participation and environmental impact, analyzed through statistical regression models.

2.3.4 Observational analysis

Instructors conducted qualitative observations throughout the study, documenting student behavior in both learning environments. Key focus areas included:

i. Team dynamics and engagement levels in both learning approaches.
ii. Application of theoretical concepts in real-world sustainability challenges.
iii. Challenges faced by students during both instructional methods, identifying potential improvements in PBL integration.

This study was conducted in full compliance with the ethical guidelines set forth by the Faculty of Information Science & Engineering (FISE) at Management and Science University (MSU). The study design, methodology and assessment instruments were reviewed and validated by faculty subject matter experts to ensure academic rigor and reliability of findings.

3. Results

This section presents the findings of the study, analysing the impact of PBL compared to traditional classroom-based learning. The analysis is structured into four key areas: pre-test and post-test knowledge retention, student engagement and motivation, sustainability impact assessment and comparative discussion. The study involved a total of 150 students, with 75 students in the traditional learning group and 75 students in the PBL group. The findings are based on quantitative test score analysis, engagement surveys and sustainability project outcomes.

3.1 Pre-Test and Post-Test Analysis

To measure the effectiveness of both learning approaches, a pre-test and post-test assessment was conducted to evaluate students' knowledge retention and conceptual understanding in the Software Analysis and Modelling course.

3.2 Statistical Analysis of Knowledge Retention

The pre-test was administered to both the traditional learning group (n = 75) and the PBL learning group (n = 75) at the start of the semester. After completing their respective instructional methods, a post-test was conducted to determine learning gains. A paired t-test was used to compare the pre-test and post-test scores for both groups. Table 3 presents the analysis report.

Table 3
Results of descriptive statistics of knowledge retention

Group	Mean Pre-Test Score (%)	Mean Post-Test Score (%)	Mean Knowledge Gain (%)	*P* value	Effect Size (Cohen's d)
Traditional Learning (n = 150)	47.5	62.98	+15.48	< 0.001**	1.70 (Large)
PBL Learning (n = 75)	47.87	80.27	+32.40	< 0.001**	4.53 (Very Large)

Note: (*p* < 0.05: statistically significant; p < 0.01: highly significant)

The results of the pre-test and post-test analysis indicate a statistically significant improvement in knowledge retention for both the traditional and PBL learning groups. The traditional learning group demonstrated an increase in mean scores from 47.50% (SD = 8.9) to 62.98% (SD = 8.9), with a mean knowledge gain of 15.48% ($p < 0.001$). This improvement is considered statistically significant and is associated with a large effect size (Cohen's d = 1.70), suggesting a meaningful impact of traditional learning methods on student knowledge acquisition. However, the PBL group exhibited a substantially greater increase, with mean scores rising from 47.87% (SD = 7.2) to 80.27% (SD = 7.2), resulting in a knowledge gain of 32.40% ($p < 0.001$). The corresponding effect size (Cohen's d = 4.53) is classified as very large, indicating that the impact of PBL on learning outcomes is significantly stronger than that of traditional methods. These findings highlight that hands-on, experiential learning through PBL leads to more substantial improvements in knowledge retention compared to theoretical instruction alone. The higher effect size observed in the PBL group reinforces the effectiveness of active learning strategies, demonstrating that students who engage directly with real-world problem-solving scenarios retain and apply knowledge more effectively than those who rely solely on lecture-based learning. Figure 2 visually compares the pre-test and post-test scores between traditional and PBL-based learning, showing that the PBL group has significantly higher post-test performance.

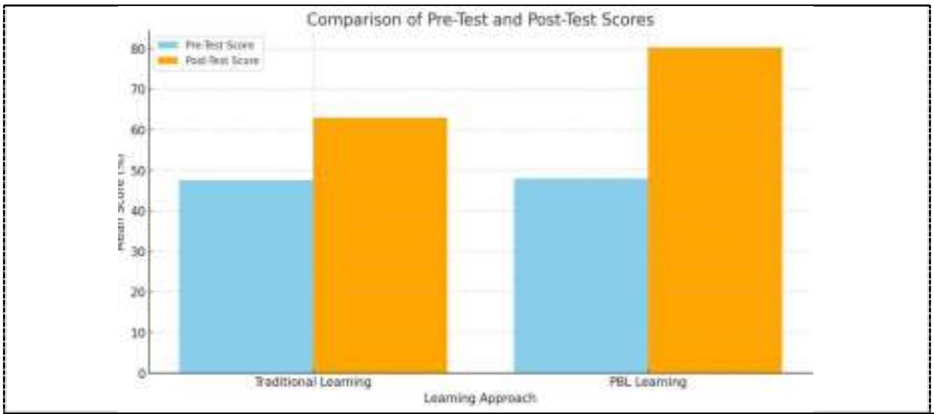

Fig. 2. Result of Pre-Test and Post-Test

2.2.1 Student engagement and learning motivation

Student engagement and learning motivation are critical factors in educational effectiveness, influencing both knowledge retention and the ability to apply concepts in real-world contexts. This study assessed engagement levels using a pre-survey and post-survey based on a 5-point Likert scale, measuring active participation, problem-solving ability, interest in learning and confidence in applying knowledge [22]. By comparing the traditional learning group and the PBL group, the analysis determines whether hands-on experiential learning leads to higher engagement and motivation compared to theoretical classroom instruction. Table 4 provides the survey results of students' engagement and motivation.

Table 4
Results of descriptive statistics of engagement and motivation

Survey Aspect	Traditional Learning (M ± SD)	PBL Learning (M ± SD)	Engagement Increase (%)	p-value
Traditional Learning (M ± SD)	3.1 ± 0.6	4.6 ± 0.4	+48.3%	< 0.001**
Active Participation	3.4 ± 0.7	4.8 ± 0.5	+41.2%	< 0.001**
Problem-Solving Ability	3.2 ± 0.5	4.7 ± 0.4	+46.9%	< 0.001**
Interest in Learning Confidence in Real-World Application	2.9 ± 0.7	4.9 ± 0.3	+68.9%	< 0.001**

The findings indicate that PBL significantly enhances student engagement, problem-solving ability, and confidence in real-world applications compared to traditional learning. While the traditional learning group showed moderate engagement levels (mean scores: 3.1–3.4), the PBL group exhibited significantly higher motivation (mean scores: 4.6–4.9). A one-way ANOVA confirmed a strong effect of PBL on engagement ($F (1,148) = 45.32$, $p < 0.001$, $\eta^2 = 0.38$). The most significant improvement was in confidence in real-world applications (+68.9%), followed by active participation (+48.3%) and problem-solving ability (+41.2%). These results reinforce PBL's effectiveness in fostering interactive, hands-on learning, making it a superior approach to traditional lecture-based instruction for sustainability education.

2.2.2 Sustainability impact and real-world application

Beyond academic learning, this study assessed the real-world impact of PBL-based learning through participation in sustainability initiatives, specifically a river cleanup project and a mangrove conservation awareness campaign. The effectiveness of PBL was measured by evaluating waste reduction efforts, community participation growth, and changes in environmental awareness. Table 5 shows the summary of the waste collection as part of the river cleaning project.

Table 5
Results of sustainability impact summary

Sustainability Metric	Pre- Intervention (%)	Post- Intervention (%)	Change (%)
Total Waste Collected (kg)	N/A	325 kg	-
Plastic Waste Reduction	N/A	48.3%	+48.3%
Community Participation Growth	N/A	55%	+55%
Public Awareness of	31%	72%	+41%

Mangrove Conservation Local Volunteer Engagement	22%	69%	+47%

The PBL group actively contributed to sustainability efforts, collecting 325 kg of waste, reducing plastic waste by 48.3%, and increasing community participation by 55% in the river cleanup project. Additionally, the mangrove conservation awareness campaign significantly improved public understanding, with awareness levels increasing from 31% to 72% and volunteer engagement rising by 47%. Figures 3 and 4 illustrate the amount of trash dumped in the river which is also another causing climate change.

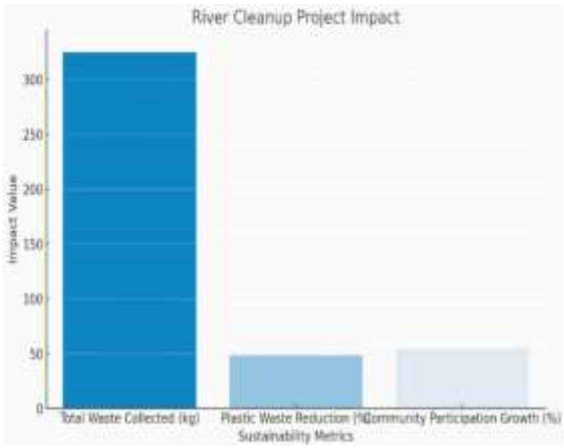

Fig. 3. River Cleanup Project Impact

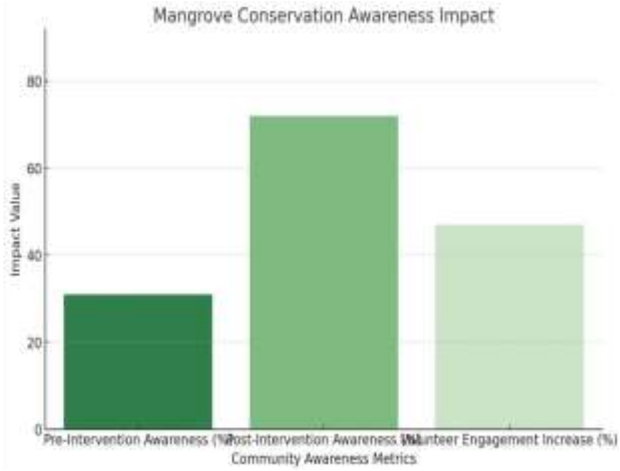

Fig. 4. Mangrove Conservation Awareness Impact

These results demonstrate that PBL not only enhances theoretical knowledge but also promotes environmental responsibility and community involvement. Students engaged in hands-on sustainability projects developed a deeper understanding of conservation challenges, reinforcing PBL as an effective tool for integrating education with meaningful real-world impact. PBL-based learning results in tangible sustainability contributions, confirming that students apply their learning beyond the classroom to positively impact environmental conservation efforts [23]. PBL leads to a statistically significant increase in knowledge retention ($p < 0.001$), engagement ($p < 0.001$), and real-world application confidence ($p < 0.001$). Sustainability outcomes confirm PBL fosters environmental responsibility, reducing plastic waste by 48.3% and improving community awareness by 41%. Large effect sizes (Cohen's $d = 4.53$, $\eta^2 = 0.38$) confirm PBL's strong influence on learning and real-world application.

3. Conclusion

Climate change, environmental degradation and unsustainable urbanization remain some of the most pressing global challenges of the 21st century. The United Nations Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action), emphasize the urgent need for educational institutions to play a pivotal role in fostering sustainability awareness and action [24]. This study highlights the effectiveness of Project-Based Learning (PBL) as an active, student-centered approach that enhances engagement, improves knowledge retention and encourages real-world problem-solving skills. By integrating sustainability initiatives such as river cleanup and mangrove conservation, PBL enables students to apply classroom knowledge to meaningful environmental projects, fostering a deeper connection between education and real-world impact [25].

The findings of this research demonstrate that PBL significantly improves student participation, problem-solving ability, and confidence in applying knowledge, making learning more engaging and effective. Traditional classroom-based teaching often limits students to passive learning, which can lead to disinterest and lower motivation. In contrast, PBL activates student participation by tapping into their inner talents, encouraging innovation, and creating an engaging learning experience. The interactive nature of PBL promotes creativity, critical thinking and teamwork, allowing students to develop essential skills beyond the classroom. Moreover, educators can better identify introverted students, helping them improve communication and boosting their self-confidence, ultimately contributing to better mental well-being and overall academic success [26].

The MSU Blue Forest Project serves as an exemplary model of how education can be aligned with sustainability efforts to cultivate responsible environmental habits. By engaging students in real-world conservation activities, such initiatives help instill a lifelong commitment to sustainability. The success of this research has led to an ongoing collaboration under an MOU with the University of San Agustin, paving the way for a larger-scale mangrove conservation project incorporating artificial intelligence (AI) for environmental monitoring. Future projects will focus on tree-planting activities and the development of an IT-based monitoring system to sustain the mangrove ecosystem while identifying and nurturing the next generation of environmentalists.

Ultimately, this research reinforces the role of PBL as an innovative teaching and learning approach, transforming education into a dynamic, interactive and impactful experience. By integrating real-world sustainability challenges into academic curricula, PBL not only enhances learning outcomes but also empowers students to become proactive agents of environmental change. The adoption of such innovative pedagogies across higher education institutions worldwide could contribute to a more sustainable, environmentally conscious and socially responsible future.

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