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Research Article

Community Engagement for Enhancing Students' STEAM Literacy: Insights from the 1.5km Experiential Learning Circle in Hong Kong

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Abstract: This study investigates the impact of the 1.5km Experiential Learning Circle (ELC) in Hong Kong on students' STEAM literacy through community-based learning. The ELC framework adapts Kolb's Experiential Learning Cycle by integrating community experiences at each stage: (1) Community Engagement, where students explore local issues through field observations and interactions; (2) Community Context Reflection, where students analyze these issues from scientific, technological, and socio-environmental perspectives; (3) Knowledge in Community Settings, where students apply STEAM concepts to propose solutions; and (4) Community-Based Action, where they implement and communicate their solutions to stakeholders. Using a mixed-methods approach combining surveys, interviews, and observations, the study explores students' competence in six key domains of STEAM literacy: communication, problem identification, knowledge seeking, problem-solving, application of STEAM concepts, and decision-making. Findings reveal that students demonstrated moderate competence in all six STEAM literacy domains, with the highest scores in communicating STEAM information, problem identification, and knowledge seeking. However, challenges were observed in applying STEAM concepts to real-world contexts and making informed decisions considering ethical, environmental, and social factors. The results demonstrate the effectiveness of community-based learning in enhancing STEAM literacy, yet highlight the need for improved instructional strategies to better connect theoretical knowledge with practical applications.

Keywords: experiential learning, community-based learning, STEAM education

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1. Introduction

1.1. Background of the Study

STEAM education has gained increasing importance in Hong Kong as a response to the demand for an innovative and technology-driven workforce (Cheng & Yeh, 2022). STEAM (Science, Technology, Engineering, Arts, and Mathematics) education gained prominence following the 2015 Policy Address, which urged the Curriculum Development Council to promote it as a strategy to enhance Hong Kong's global competitiveness. The 2022 Policy Address further expanded these efforts, requiring most schools to integrate STEAM into their curricula, mainly through out-of-classroom activities. By 2022, an Education Bureau survey indicated that most schools offered extra-curricular STEAM activities with external stakeholder support. However, while most primary and secondary schools incorporated coding and I&T elements, the extent and depth of integration remained ambiguous. Despite growing interest in STEAM education, few schools incorporated dedicated STEAM classes into their formal curriculum. Instead, they explored different approaches by focusing on areas like engineering, robotics, environmental science, or the arts. Some schools also promoted learning through competitions such as hackathons, coding challenges, and innovation contests (Legislative Council Secretariat, 2023; Hong Kong Productivity Council, 2022; Hong Kong Federation of Education Workers, 2017).

However, STEAM education in Hong Kong still lacks a clear, policy-level definition, leading to inconsistencies in cross-disciplinary integration. Additionally, engineering education remains underdeveloped in secondary schools, limiting students' exposure to essential design-based problem-solving skills (Ali, 2021). These gaps highlight the need for structured, community-integrated learning models that connect STEAM education with students' everyday lives. Increasingly, some schools are addressing this challenge by integrating community engagement into STEAM educationn, using the local environment as both a learning context and a source of stakeholders to be served. These schools design projects that address real-world issues such as sustainability, accessibility, and urban development, collaborating with businesses, non-profits, and government agencies to provide students with hands-on, socially relevant learning experiences. This approach enhances problem-solving skills while fostering civic responsibility. However, many STEAM initiatives remain standalone activities disconnected from students' daily lives. This study explores how the 1.5km Experiential Learning Circle (ELC) model bridges this gap by embedding STEAM education within the local community. By transforming the areas surrounding schools into interactive learning spaces, the ELC enables students to apply STEAM concepts in meaningful, real-world contexts, strengthening their engagement and ability to innovate.

Traditional educational models often struggle to connect academic learning with real-world applications, particularly in urban settings where students may have limited exposure to hands-on, community-based learning experiences (Trilling & Fadel, 2009; Hu, 2024). The ELC in Hong Kong was developed to address this gap by integrating STEAM education with community engagement. The ELC transforms the local community – within a 1.5km radius of schools – into a dynamic learning space where students explore businesses, cultural landmarks, historical sites, government premises, and natural environments (Lau, 2024; 2025). The ELC enhances Kolb's Experiential Learning Cycle (Kolb, 1984) by embedding community-focused elements into each stage: Community Engagement, Community Context Reflection, Knowledge in Community Settings, and Community-Based Action. This approach allows students to apply STEAM concepts in real-world contexts, fostering a deeper understanding of their environment, developing innovation skills, and strengthening their role as active community participants.

STEM literacy, as defined in the context of this study, refers to the ability to identify, apply, and integrate concepts from science, technology, engineering, and mathematics to understand complex problems and innovate solutions (Washington State Legislature, 2024). The six key domains of STEM literacy include: 1) identifying STEM problems; 2) seeking new knowledge; 3) applying STEM concepts; 4) solving problems using STEM; 5) communicating STEM-related information; and 6) making decisions based on STEM (Techakosit & Nilsook, 2018). These domains emphasize critical thinking, problem-solving, creativity, and the application of scientific, technological, engineering, and mathematical principles in real-world contexts.

Incorporating the arts into STEM, transforming it into STEAM, extends these concepts by adding a creative and interdisciplinary dimension. STEAM education not only focuses on developing students' competencies in the core STEM disciplines but also fosters artistic and creative thinking, encouraging students to approach problems from multiple perspectives and innovate in diverse ways. While STEM literacy emphasizes technical and analytical skills, STEAM education integrates creative processes that enhance students' ability to think critically and solve problems in a more holistic manner.

In this study, the six domains of STEM literacy are adopted as the key measures for assessing the impact of the ELC on students' STEAM literacy. These domains help measure how students can apply interdisciplinary knowledge to community-based learning activities, demonstrating their ability to identify real-world problems, seek solutions, communicate their findings, and make informed decisions. The integration of arts within the ELC framework further enriches students' learning experiences by encouraging creativity and critical thinking, ensuring that they not only master technical skills but also develop the ability to innovate in solving complex societal issues.

1.2. Problem Statement

The gap between theoretical classroom learning and practical, community-based applications remains a critical issue in education (Pawlak & Moustafa, 2023). Many students lack opportunities to apply academic knowledge to real-world challenges, hindering their development of critical thinking, creativity, and interdisciplinary problem-solving skills essential in STEAM education (Rusmin et al., 2024). In the context of STEAM education, this gap is even more pronounced, as many activities tend to focus on isolated disciplines without meaningful integration into local, real-world contexts. The lack of community-based learning experiences restricts students from applying interdisciplinary knowledge to solve societal issues, reducing their capacity for innovation and limiting the development of holistic, practical skills that can address the complex challenges of today's world. Integrating community engagement into STEAM education can bridge this divide, allowing students to make meaningful connections between their learning and the environments around them.

This study explores how the ELC model enhances STEAM literacy by fostering deeper community engagement. It examines how students apply interdisciplinary knowledge to address local challenges, how teachers facilitate these experiential learning opportunities, and how community partnerships enrich STEAM education, creating a more holistic and socially relevant educational framework.

1.3. Significance of the Study

This study is significant in demonstrating how the ELC model enhances STEAM literacy by fostering deeper community engagement and real-world problem-solving. By integrating interdisciplinary knowledge application, it strengthens students' critical thinking, innovation, and ability to address local challenges. For educators, the study provides insights into effective teaching strategies that connect classroom concepts with authentic experiences, enhancing student motivation in STEAM subjects. It also informs policymakers and school administrators on the value of community partnerships in enriching STEAM education, offering a model for leveraging local resources to create a holistic and socially relevant learning environment. Moreover, by equipping students with the skills to engage with real-world issues, the study reinforces the role of education in promoting responsible citizenship and social innovation, ultimately strengthening the connection between schools and their communities.

2. Materials and Methods

2.1. Research Design and Participants

This study adopts a mixed-methods approach, combining both quantitative and qualitative data collection to explore the impact of ELC on students' STEAM literacy, engagement, and entrepreneurial thinking. The quantitative component involves a structured questionnaire administered to secondary school students, aimed at assessing their development of STEAM literacy. The qualitative component consists of semi-structured interviews with teachers to gather deeper insights into students' learning experiences, interdisciplinary applications, and the effectiveness of community-based STEAM activities.

The research was conducted at a secondary school in Hong Kong that actively engages in the ELC activities. The participants include 30 secondary school students who completed the questionnaire and five teachers who participated in in-depth interviews. Additional input from selected community stakeholders provided further context regarding the ELC's influence on students' innovation and problem-solving abilities.

2.2. Population and Sampling

Purposive sampling was used to select participants with direct experience in the ELC. Data were collected through student reflections, teacher observations, and community partner feedback, offering a comprehensive view of how the ELC supports the development of STEAM literacy. To ensure diversity, students from a range of academic backgrounds and learning abilities were included. Ethical standards were strictly followed throughout the study. Informed consent was obtained from all participants and, where necessary, from their guardians. Participation was entirely voluntary, and confidentiality and anonymity were carefully maintained. Special attention was given to fairly representing the voices of students with different learning needs, ensuring that the findings reflected an inclusive understanding of STEAM literacy growth through the ELC experience.

2.3. Data Collection Instruments

The study employed both quantitative and qualitative instruments for data collection. For the quantitative data, this study developed a structured questionnaire to assess students' STEAM literacy development. The questionnaire covered six core competency domains: identifying STEAM problems, seeking new knowledge, applying STEAM concepts, solving problems using STEAM, communicating STEAM-related information, and making decisions based on STEAM. Each domain consisted of 4-6 closed-ended questions (totaling 30 questions) rated on a five-point Likert scale. In addition, two open-ended questions were included to gather students' reflections on their learning experiences and suggestions for improvement. For the qualitative data, semi-structured interviews were conducted with five teachers involved in ELC activities. The interviews aimed to explore teachers' perspectives on students' engagement, interdisciplinary learning, and problem-solving skills. Teachers provided insights into how students applied STEAM concepts to real-world community contexts and how entrepreneurial thinking was fostered through ELC. These interviews complemented the questionnaire data, enriching the findings with qualitative context.

2.4. Data Processing and Analysis

Data were analyzed using both quantitative and qualitative methods to ensure a comprehensive understanding of the research objectives. For Quantitative Analysis, the questionnaire data were analyzed using descriptive statistics to summarize trends in students' self-assessed STEAM literacy across the six competency domains. Reliability analysis was performed using Cronbach's Alpha to ensure internal consistency ($\alpha > 0.7$). Additionally, variations in student confidence and competency across different STEAM domains were examined to identify patterns. For qualitative analysis, thematic analysis was applied to the teacher interview transcripts to identify key patterns related to student engagement, interdisciplinary learning, and entrepreneurial skill development. The transcripts were coded into themes aligned with the research objectives. Triangulation was used by comparing teacher insights with the questionnaire data to enhance validity and reliability. Member-checking was also conducted to ensure the accuracy and representation of teachers' perspectives in the findings.

2.5. Validity and Reliability Considerations

The questionnaire was designed based on established STEAM literacy frameworks and relevant literature to ensure comprehensive coverage of key competency areas in STEAM learning. It also incorporated artistic creativity-related questions within each competency domain, ensuring the holistic nature of STEAM education was represented. This inclusion of artistic elements reflects STEAM's emphasis on cross-disciplinary connections and innovation.

To ensure reliability, each competency domain contained a minimum of two questions. Cronbach's Alpha was calculated to verify internal consistency, ensuring the reliability of the constructs ($\alpha > 0.7$). The mixed-methods approach, combining quantitative and qualitative data, enhanced the comprehensiveness of the findings. The combination of numerical data from the questionnaire and qualitative reflections from teacher interviews allowed for a nuanced understanding of the effectiveness of community-based STEAM learning on student development.

3. Results

This section presents the findings on how community-based learning activities influenced students' STEAM literacy across six key domains. The data collected provide insights into students' strengths and areas for improvement when engaging with real-world, interdisciplinary challenges. This study aims to examine the effectiveness of community-based learning initiatives in enhancing students' communication, problem-solving, knowledge-seeking, decision-making, and application skills related to STEAM.

Table 1. The impact of community-based learning activities on students' STEAM literacy.

Domains	M	SD
The ability to communicate STEAM-related information	3.51	0.95
The ability to identify STEAM problems	3.45	0.98
The ability to solve problems using STEAM	3.45	1.01
The ability to seek new knowledge	3.45	1.15
The ability to make decisions based on STEAM	3.26	0.96
The ability to apply STEAM concepts	3.09	1.05

The results (table 1) indicate that students exhibited a moderate level of competence across all six assessed domains, with mean scores ranging from 3.09 to 3.51. Of these, students demonstrated the strongest performance in their ability to communicate STEAM-related information ($M = 3.51$, $SD = 0.95$), suggesting a relative confidence in articulating and presenting their ideas. This may be attributed to the collaborative, peer-interactive, and presentation-focused nature of community-based learning activities.

Students also exhibited notable strengths in their ability to identify STEAM problems

(M = 3.45, SD = 0.98), solve problems using STEAM (M = 3.45, SD = 1.01), and seek new knowledge (M = 3.45, SD = 1.15), reflecting their growing aptitude for critical thinking and problem-solving when addressing real-world community challenges. The relatively higher standard deviation for the knowledge-seeking domain suggests a broader range of variability, likely influenced by individual differences in motivation or previous exposure to independent inquiry-based learning.

In contrast, decision-making based on STEAM knowledge yielded a lower score (M = 3.26, SD = 0.96), highlighting a potential area for improvement. This result underscores the need for more structured support to strengthen students' abilities to make informed, evidence-based decisions, considering ethical, environmental, and social factors in complex, real-world scenarios.

The ability to apply STEAM concepts (M = 3.09, SD = 1.05) scored the lowest among all domains, revealing a significant gap in students' capacity to transfer theoretical knowledge into practical, community-based applications. This finding suggests a need for more hands-on, experiential learning opportunities that bridge the gap between academic learning and its real-world implementation. The relatively high standard deviation in this domain further suggests a considerable variation in students' abilities, potentially reflecting differing levels of prior experience with interdisciplinary learning or practical application.

While community-based learning activities effectively foster students' communication and problem-identification skills, further interventions are necessary to enhance their ability to apply STEAM concepts and make informed decisions. These findings highlight the need for a more integrated, hands-on approach to ensure that students can not only understand but also apply their STEAM knowledge in meaningful, real-world contexts.

3.1 The Ability to Communicate STEAM-Related Information

Effective communication is a priority in the curriculum, as students regularly present their work to both peers and community members. This domain scores relatively well, with students showing confidence in presenting findings and explaining concepts clearly (Mean = 3.60, SD = 0.96 and Mean = 3.60, SD = 0.91).

The STEAM coordinator described the communication component of the Smart Home Design Project:

Students not only created prototypes but also had to explain their designs to elderly participants, blending technical accuracy with language accessible to non-experts. Throughout the process, students engaged in direct discussions with the elderly to understand their needs, gather feedback on initial designs, and refine their solutions based on the participants' lived experiences. This dual focus - on technical content and community-friendly delivery – helped sharpen their communication skills while fostering meaningful intergenerational dialogue.

Another Design and Technology teacher emphasized how the initiative extends learning beyond the classroom, allowing students to apply their skills in meaningful, community-driven contexts:

The program offers students an opportunity to learn beyond the classroom, where they can unleash their potential and showcase their talents by serving different age groups in the community. Through these intergenerational services, students not only respond to community needs but also strengthen social bonds between the elderly and younger generations. This exchange fosters intergenerational harmony and brings positive impacts to students, the community, and the school.

A Science teacher reflected on students' growth in science communication:

Similarly, in the water and air quality monitoring projects, students presented their scientific findings to the community using clear, accessible language, further enhancing their science communication skills and demonstrating how environmental data could be tied to everyday life concerns of the elderly.

However, students feel less confident when using more technical communication methods such as visualizing data through charts, graphs, or infographics (Mean = 3.24, SD = 1.01 and Mean = 3.44, SD = 0.71). The STEAM coordinator recommended enhancing the curriculum with explicit training in science communication techniques, particularly focusing on data visualization and storytelling with evidence.

3.2 The Ability to Identify STEAM Problems

The key objective of the school's community-friendly design and technology curriculum is to develop students' ability to recognize and articulate real-life problems in their local community through a STEAM lens. This domain reflects students' capability to observe and identify such problems, and the results indicate moderate to strong competence in this area. Notably, one item (Mean = 3.64, SD = 0.86) stands out as one of the highest scoring, indicating students' confidence in identifying community-related STEAM problems through direct observation and inquiry.

The STEAM coordinator shared the F.3 Smart Home Design Project as an example, explaining:

Students directly observed how elderly residents struggled with traditional home appliances, and from these observations, they identified real design problems that required innovative solutions. Inviting the elderly into the classroom to demonstrate their daily challenges gave students valuable first-hand exposure.

Beyond problem identification, the mentorship model strengthened students' awareness of intergenerational technology needs. A former principal and STEAM educator elaborated:

Students can develop and apply innovative technologies for the elderly. Through a mentorship model involving both teachers and students, they train elderly individuals to use technology, creating a community of tech-savvy seniors. This allows them to leverage their life experiences creatively and use technology to bridge the intergenerational gap.

A Science teacher highlighted the students' ability to relate scientific investigation to community issues:

In the environmental monitoring projects, students identified issues like deteriorating water quality in Tuen Mun River and air pollution hotspots near the school. These problems were directly relevant to community health, particularly for the elderly, showing students' ability to connect scientific observation to community well-being.

Despite strong initial problem identification, variations exist within this domain. One item measuring students' confidence in exploring the causes of these problems through self-directed research (Mean = 3.16, SD = 1.14) reveals slightly lower confidence. This suggests that while students excel in recognizing problems, they still require guidance to conduct deeper investigations. Overall, the findings underscore the effectiveness of community-based learning in exposing students to authentic, observable issues, yet additional instructional support is needed to help them systematically explore the underlying scientific, social, and environmental causes.

3.3 The Ability to Solve Problems Using STEAM

The STEAM coordinator stressed that problem-solving is at the heart of community-friendly STEAM education, as students encounter unpredictable challenges during real-life projects. This domain assesses students' ability to apply critical and creative thinking to solve complex problems, with results showing moderate confidence. One item (Mean = 3.60, SD = 0.96) indicates particular strength in interpreting and analyzing data collected during community investigations.

The STEAM coordinator shared an example from the Community Ukulele and Classical Guitar Workshop:

Students needed to solve technical problems on the spot, adjusting string tension for sound quality or modifying body designs to improve resonance. These hands-on troubleshooting experiences helped students practice real-world problem-solving, supported by both scientific principles and creative thinking. In addition, students were able to teach the elderly participants how to make their own ukuleles and guitars, facilitating a meaningful transfer of knowledge between generations and reinforcing students' understanding through teaching.

A Science teacher emphasized the hands-on problem-solving experiences students encountered:

In environmental monitoring, students also tackled real-world technical challenges, such as calibrating sensors for accurate water and air quality readings and adapting measurement techniques to field conditions.

However, students' confidence in developing final workable solutions based on their analysis (Mean = 3.48, SD = 0.87) is lower. This suggests that while students can identify problems and analyze data, they need more structured guidance in translating insights into well-developed, innovative solutions. The STEAM coordinator recommended further training in design thinking and iterative prototyping to bridge this gap.

3.4. The Ability to Seek New Knowledge

Nurturing students' curiosity and their ability to seek out new knowledge is central to the curriculum's experiential learning approach. This domain captures students' willingness and ability to actively gather information when faced with STEAM-related challenges in their communities. One item (Mean = 3.68, SD = 0.95) reflects this strength, showing students' confidence in synthesizing information from various sources.

The STEAM coordinator cited the F.2 Chocolate Molding Project as a powerful example:

When students realized that chocolate stuck to certain materials or cooled unevenly, they actively sought *out scientific explanations – learning about melting points, surface textures, and the chemistry of different materials. This self-directed research stemmed from their desire to improve their designs for the elderly participants.*

A Design and Technology teacher also highlighted how the community context drives students' interest in identifying problems and thinking about solutions:

Community-based projects provide a unique opportunity for students to connect their learning to real-world issues. When students see the challenges faced by the elderly or their neighbors, it sparks a genuine interest in finding solutions. For example, in the Smart Home Design Project, students didn't just design for the sake of it – they understood that their designs could improve the quality of life for real people in their community. This direct connection to the community not only motivates them but also gives them the context to think critically about how they can apply their STEAM knowledge to make a tangible difference.

A Science teacher observed the students' self-initiated research and learning beyond the classroom:

When faced with unexpected environmental data from the water and air monitoring projects, students conducted further research into pollution sources and remediation methods, demonstrating self-directed learning skills in a real-world context.

While students demonstrate curiosity and a strong motivation to learn, their confidence in using scientific research methods to investigate problems (Mean = 3.32, SD = 1.18) remains moderate. This indicates a need for more structured training in formal inquiry processes, such as designing systematic investigations and interpreting data rigorously. To strengthen their research skills, students would benefit from additional scaffolding.

3.5. The Ability to Make Decisions Based on STEAM

Decision-making, especially when balancing scientific, social, and economic factors, remains a challenging aspect of students' development. This domain focuses on students' ability to make evidence-based decisions in the face of complex, real-world trade-offs, with results showing moderate but uneven performance. Students' confidence in weighing scientific data against community opinions (Mean = 3.44, SD = 0.71) and making balanced decisions (Mean = 3.04, SD = 1.06) is mixed.

The STEAM coordinator reflected on this challenge during the Chocolate Molding Project:

Students had to choose between biodegradable materials, which were eco-friendly but costly, or cheaper plastic molds that were easier for elderly participants to use. Balancing these competing priorities, such as sustainability, cost, and usability, really challenged their decision-making abilities.

A Science teacher remarked on students' decision-making skills when managing real-world limitations:

Similarly, during environmental monitoring, students had to decide which parameters to prioritize (e.g., pH levels, particulate matter) based on their relevance to community health and available resources, reinforcing their ability to make informed decisions under real-world constraints.

Additionally, students' confidence in handling complex trade-offs between environmental, economic, and social factors (Mean = 3.04, SD = 0.71) remains limited. The STEAM coordinator recommended that future projects deliberately incorporate ethical debates, cost-benefit analyses, and structured decision-making exercises to strengthen students' holistic reasoning and interdisciplinary thinking.

3.6. The Ability to Apply STEAM Concepts

Applying STEAM knowledge in practical contexts remains one of the curriculum's biggest challenges. The results confirm this, with all items in this domain scoring at the lower end. In particular, students' confidence in transferring theoretical knowledge into practical solutions (Mean = 2.92, SD = 1.12) and applying scientific concepts to explain their design choices (Mean = 2.96, SD = 1.14) are notably low.

The STEAM coordinator highlighted the F.1 Thumb Piano Case Project as a case in point:

Students enjoyed designing and sewing protective cases for thumb pianos used by elderly residents, but they struggled to explain how their material choices related to scientific properties like durability, flexibility, or thermal resistance. This exposed the gap between knowing scientific concepts and applying them meaningfully.

The former principal emphasized the importance of structured community-based learning in addressing these challenges:

This provides students with a platform to understand community needs. By engaging in creative projects, they gain a deeper understanding of society in a tangible and practical manner.

A Science teacher noted the students' efforts to apply theoretical knowledge in practice:

In the environmental projects, students were challenged to apply concepts like chemical contamination, biological indicators, and particulate physics to interpret water and air quality results, demonstrating growing but still developing capabilities in applying STEAM knowledge in context.

These findings highlight the need for explicit guidance and structured reflection in integrating theoretical knowledge with practical design decisions. Embedding mentorship and iterative problem-solving into community-based projects, students can develop the confidence and analytical skills necessary to apply STEAM concepts in meaningful, innovative ways.

4. Discussion

The findings demonstrate that the Community Engagement stage plays a crucial role in enhancing students' ability to identify STEAM-related problems within their neighborhoods. Through field visits and community observation, students directly encountered sustainable development issues, allowing them to recognize how scientific, technological, and environmental knowledge could explain and address the challenges they observed. The water quality monitoring in the Tuen Mun River and the air quality monitoring around the school were particularly impactful. Students observed firsthand how environmental problems intersected with community health, especially affecting vulnerable groups such as the elderly. These real-world encounters reinforced the value of authentic, experiential learning, making abstract STEAM concepts tangible and urgent.This hands-on immersion aligns with Kolb's (1984) notion of Concrete Experience, but with an added community relevance dimension (Kolb & Kolb, 2005), which deepened students' emotional connection to the problems. The authentic learning emerges when knowledge acquisition is anchored in meaningful, real-life experiences directly relevant to learners' daily lives. STEM education aims to enhance students' learning by incorporating activities that foster their 21st-century skills (Education Bureau, 2016; 2020). By strengthening their ability to identify problems, authentic community-based learning transforms students from passive learners into active observers, equipping them to recognize and analyze the complex STEAM-related challenges in their everyday environments.

Additionally, research highlights the importance of evaluating STEAM education beyond traditional academic outcomes. Instead of focusing solely on students' mastery of technical skills, assessments should consider interdisciplinary knowledge application, problem-solving abilities, and the capacity to engage with real-world challenges (Wong et al., 2025). The findings also highlight how community engagement stimulates students' ability to seek new knowledge. As they observed these problems, students naturally began asking why such issues existed and what scientific explanations could help make sense of them. This desire to actively seek out new knowledge reflects how place-based learning stimulates inquiry by situating learning within the students' lived environments, making knowledge pursuit directly relevant and purposeful (Honey et al., 2014). Through guided exploration, students started to link their observations to environmental science, engineering, and even social issues, demonstrating the value of integrating community contexts into STEAM education.

In the second stage, Community Context Reflection, students progressed from identifying problems to investigating their underlying causes and system dynamics. This reflective process corresponds to Reflective Observation in Kolb's (1984) learning cycle. When students were asked to consider not only scientific explanations but also social, cultural, and ecological factors shaping the problems, they developed a more interdisciplinary perspective. Hands-on engagement with the local environment – such as field observations, interactive experiments, and community-based projects – helped bridge this gap, allowing students to develop foundational scientific skills like observing, predicting, and problem-solving in real-world contexts (Setyawan, 2024). However, findings indicate lower confidence in using formal scientific research methods, showing a clear gap between observation and systematic scientific inquiry. This stage also fostered an early ability to apply STEAM concepts, as students started to combine scientific thinking with socio-environmental reflection, recognizing that community problems cannot be fully understood through a single disciplinary lens.

The third stage, Knowledge in Community Settings, required students to synthesize their emerging understanding by applying STEAM concepts to explain, interpret, and propose preliminary solutions to real-world problems. This phase aligns with Kolb's (1984) Abstract Conceptualization, but within a community-based framework where theoretical knowledge must be reconciled with practical constraints and local priorities. Findings reveal that students struggled with this process, reflecting the persistent "theory-practice gap" in STEM education (Honey et al., 2014), in which knowledge acquired in classrooms remains compartmentalized and disconnected from real-world application. This disconnect arises from the traditional structuring of STEAM subjects as isolated disciplines, limiting students' ability to transfer knowledge across domains.

When students learn within community contexts, they come to see scientific and technological ideas not just as abstract theories, but as embedded in their daily lives — in the air they breathe, the water they drink, and the infrastructure that supports them (Lau, 2025). This shift aligns with Situated Learning Theory (Lave & Wenger, 1991), which posits that learning is most effective when it occurs through participation in authentic social practices. In this model, community-based learning functions as a legitimate peripheral participation process, in which students move from passive observers to active problem-solvers, engaging with real-world complexities that require interdisciplinary thinking. As students interact with their environment and apply STEAM knowledge in context, they gradually build confidence in their ability to bridge theory and practice, effectively strengthening their scientific literacy and problem-solving skills within a dynamic, real-world setting.

The Community-Based Action stage required students to move beyond analysis and actively engage in problem-solving using STEAM knowledge. This phase aligned with Active Experimentation in Kolb's (1984) learning cycle while emphasizing community participation and civic engagement. Students had to communicate their findings and proposed solutions to local stakeholders, enhancing their ability to translate scientific data into accessible formats, develop clear visualizations, and frame scientific explanations in ways that were understandable and persuasive to non-expert audiences. An important objective was to foster participatory citizenship, as suggested by Kassab, DeFranco, and Laplante (2020) as well as Suduc, Bîzoi, and Gorghiu (2018), by encouraging students to address real-world challenges through a STEAM educational approach.

As a result, they developed a deeper and more contextualized understanding of local problems and potential solutions. Post-test questionnaire responses (Santos et al., 2023) indicated that students gained a clearer understanding of their civic duties in relation to both local and global issues. Additionally, they began developing an emerging ability to make decisions based on STEAM knowledge, weighing scientific evidence alongside social, economic, and environmental trade-offs. However, findings showed that students felt less confident in making evidence-based decisions, highlighting the need for further practice in evaluating trade-offs and balancing multiple forms of evidence. Despite this, they gained valuable insights into the complexity of real-world decision-making, where scientific knowledge must be considered alongside community priorities and resource limitations. This stage demonstrated that authentic community learning fosters civic STEAM literacy, enabling students to not only deepen their scientific understanding but also apply and communicate their knowledge responsibly in public decision-making contexts.

5. Conclusions

This study examined how community-based learning initiatives foster students' communication, problem-solving, knowledge-seeking, decision-making, and application skills in STEAM education. The findings demonstrated that through a structured progression – starting with community engagement, reflection, knowledge application, and culminating in community-based action – students became more observant, inquisitive, and purposeful in addressing real-world STEAM challenges. Authentic experiences anchored in local contexts strengthened their ability to communicate, seek interdisciplinary knowledge, and recognize the social dimensions of scientific issues, reflecting key principles of experiential and situated learning.

However, while students developed critical observation and inquiry skills, they showed lower confidence in applying STEAM concepts to make complex, evidence-based decisions, revealing the persistent challenge of bridging theoretical knowledge with practice. This underscores the need for sustained, interdisciplinary, and action-oriented learning experiences.

Overall, the study supports the crucial role of community-integrated STEAM education in building 21st-century competencies, positioning students not just as learners but as active participants in their communities. Future research should further explore how long-term involvement in community-based projects shapes students' problem-solving capacities, ethical decision-making, and career trajectories, and how best to support students in integrating technical, social, and environmental considerations in real-world contexts.

Further research could examine how extended participation in community-based projects influences students' problem-solving, ethical reasoning, and future aspirations. Future studies could also explore more effective strategies for helping students balance technical, social, and environmental considerations when applying STEAM knowledge in practice

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