Reimagining STEM Learning: A Comparative Analysis of Traditional and Service Learning Approaches for Social Entrepreneurship

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***Abstract*—This study examines a practical teaching and learning cycle tailored to integrate cutting-edge technologies (artificial intelligence (AI) and machine learning (ML) game development) and social entrepreneurship within a "STEM with meaning" approach. This cycle, rooted in service learning and the 5E constructivist teaching model (engage, explore, explain, elaborate, and evaluate), seeks to move beyond traditional lecture-based methods by promoting a deeper understanding of technology's societal impacts. Through a comparative analysis involving experimental and comparison groups, we evaluate the cycle's effectiveness in enhancing students' problem-solving skills, empathy, knowledge application, and sense of social responsibility—essential qualities for successful social entrepreneurs. This article contributes to the burgeoning field of entrepreneurship education by demonstrating the value of a pedagogical approach that combines AI, ML, and game development with a strong emphasis on social entrepreneurship. Our results advocate a shift toward educational models that prepare students with technical skills and the awareness and capabilities needed to address complex social issues. Through this research, we highlight the critical role of innovative teaching methods in cultivating the next generation of socially responsible entrepreneurs, thereby enriching both the educational landscape and society at large.**

***Index Terms*—Constructivist teaching, service learning (SL), social entrepreneurship, special education needs, science, technology, engineering, and mathematics (STEM) education.**

I. Introduction

ENTREPRENEURSHIP and social entrepreneurship, while sharing a foundational premise of innovation and venture creation, diverge significantly in their core objectives and outcomes [1]. Traditional entrepreneurship primarily focuses on creating and growing businesses to generate profit and economic value [2]. In contrast, social entrepreneurship places a central emphasis on addressing societal challenges, leveraging business principles and practices to achieve social change and impact [3]. This distinction underscores the unique mission of social entrepreneurs to pursue sustainable solutions to pressing social issues, often prioritizing social value over financial gain.

A critical examination of traditional engineering curricula reveals a notable gap in fostering social responsibility among students [4]. Conventional teaching methodologies tend to emphasize the acquisition of solid knowledge and technical competencies, particularly in science, technology, engineering, and mathematics (STEM) disciplines, without necessarily embedding these skills within a broader context of societal impact [5], [6]. This approach may inadvertently limit students' capacity to apply their expertise in ways that contribute meaningfully to community welfare and global challenges.

The "STEM with meaning" approach seeks to bridge this gap by integrating the principles of social entrepreneurship into STEM education. It posits that STEM education, when infused with the ethos of social entrepreneurship, can more effectively prepare students to utilize their skills for the greater good. Furthermore, the convergence of cutting-edge technologies, such as machine learning (ML), artificial intelligence (AI), computer vision, and game development presents unprecedented opportunities for innovative solutions to societal problems [7], [8], [9], [10], [11], [12]. By integrating these technologies within a unified curriculum, educators can offer students a holistic learning experience that spans multiple domains of expertise. This interdisciplinary approach not only enriches students' technical skills but also enhances their ability to think critically and creatively about the application of technology in addressing complex social issues.

Incorporating these elements into STEM education requires a shift away from traditional, compartmentalized teaching methods toward a more integrated and purpose-driven learning environment. Therefore, universities can equip students with the knowledge, tools, and mindset necessary to become effective social entrepreneurs—individuals capable of leveraging technology to foster social innovation, drive positive change, and create sustainable impact in the world.

This article examines the integration of social entrepreneurship with AI, ML, and game development education, employing a "STEM with meaning" approach through service learning (SL) and the engage, explore, explain, elaborate, and evaluate (5E) model of constructivist teaching [13]. We detail a curriculum

Received 5 February 2024; revised 7 July 2024 and 21 October 2024; accepted 26 October 2024. Date of publication 6 November 2024; date of current version 2 December 2024. This work was supported by the Hong Kong Polytechnic University under Grant 49QB and Grant CE1D. *(Corresponding author: Chen Li.)*

This work involved human subjects or animals in its research. Approval of all ethical and experimental procedures and protocols was granted by PolyU Institutional Review Board (PolyU IRB) (or its Delegate) under Application No. HSEARS20230202005.

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Digital Object Identifier 10.1109/TLT.2024.3492352

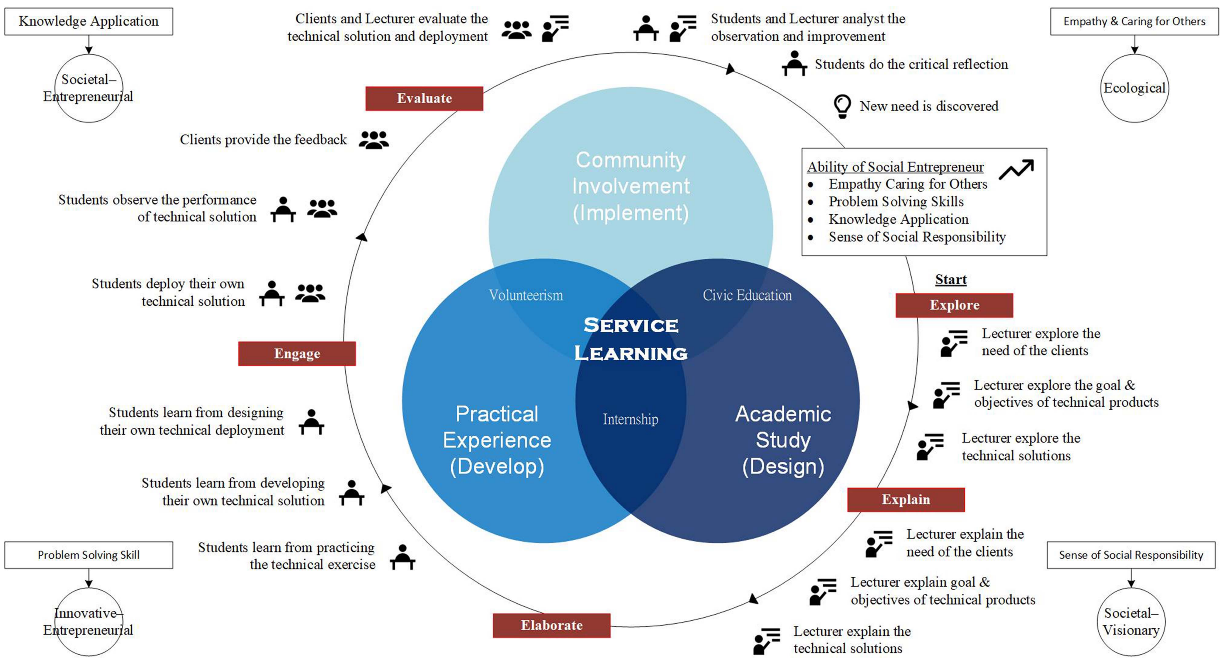

Fig. 1. Proposed teaching and learning cycle.

design that equips students with technical skills alongside a commitment to social innovation. By comparing outcomes from two courses via questionnaires, we evaluate the effectiveness of our pedagogical model in fostering both technical proficiency and a social entrepreneurial mindset. Our findings aim to demonstrate the potential of integrating advanced technology education with social entrepreneurship, preparing students to use their skills to address societal challenges meaningfully.

II. Literature Review

Social entrepreneurs play a crucial role today because they develop new and creative ways to solve important social problems [14]. They emphasize delivering social value to the less privileged while partially behaving like profit-oriented entrepreneurs such as innovative, dedicated, opportunity-alert, persistent, and committed [15]. Some researchers also highlight their out-of-box thinking and ability to bring new stuff to the world [16]. Continuous innovation is mentioned in different research as a key indicator of successful social entrepreneurship [17]. The entrepreneurship perspective of social entrepreneurs is strongly associated with innovation and “financially independent, self-sufficient, or sustainable” [15], [18]. Therefore, becoming a successful social entrepreneur requires focusing on delivering social values and implementing strategies to attain economic efficiency.

The research investigates the contemporary phenomenon of social entrepreneurship, as elucidated by Cagarman et al. [19]. The study concludes with a 5-D social entrepreneurship model, encompassing ecological, societal-visionary, societal-entrepreneurship, innovative entrepreneurship, and economic dimensions. Due to resource constraints, we adopted the first four elements in our learning cycle, as shown in Fig. 1. The societal-visionary dimension pertains to a comprehensive perspective on society, addressing human needs, societal values, and future opportunities. The ecological dimension focuses on ecological changes and improvements. The societal-entrepreneurship dimension encompasses societal impacts, business models, and the management of startups. Finally, the innovative entrepreneurship dimension highlights innovative methods and creativity. Our learning cycle reflected these four dimensions around the core concept of social entrepreneurship.

Despite this critical role, most universities have not fully integrated social entrepreneurship into their curricula [20]. When they do offer courses on this subject, they tend to focus on community service or design projects. For example, they might have students work on projects for local community centers or service initiatives. Unfortunately, this approach is usually limited to the field of social sciences and does not capture the full potential of what social entrepreneurship can offer. In addition, there is a noticeable lack of a structured educational framework that covers the wide range of skills and knowledge needed to become a successful social entrepreneur.

A more comprehensive educational approach that goes beyond one-off events and competitions is needed. This approach should include ongoing project development, client interaction, and strategic use of ML and AI to create and implement solutions that have a real social impact. By broadening the educational scope to include these aspects, universities can better prepare students to be change makers who use technology to make a significant and lasting difference in society.

SL is an experiential educational approach [21]. The idea was raised and discussed over a century [22], [23], [24], [25], [26]. In the engineering field, Duffy et al. [27] established a foundational framework by explaining the importance of integrating SL into engineering, highlighting its potential to teach technical and social skills. Oakes et al. [28] expanded on this by providing early examples of SL projects in engineering, emphasizing the practical implementation and student benefits. Bielefeldt et al. [29] measured the added value of SL in project-based education, demonstrating improvements in student learning outcomes and engagement and explored how SL contributes to the ethical education of engineering students, showing how it fosters a sense of social responsibility. Together, these studies showcase how SL evolved from a theoretical approach to a robust educational tool, significantly enhancing engineering education by combining technical knowledge with societal impact [30], [31]. SL involves students participating in meaningful community projects to improve people's lives. SL courses are practical pedagogy for the holistic development of students while also attempting to promote the well-being of the service recipients and the community [32]. It could strengthen university students' social responsibility through meaningful service to the community with academic study [33]. The SL course brings students to travel globally [34] and to some developed cities, which can be fertile grounds for impactful dissonances and civic learning [35]. Some of the SL courses also intend to integrate engineering and nonengineering students to apply their theoretical knowledge to solve real-world problems [36].

Through SL, students can use what they learn in their academic courses to solve real-world problems. This provides students with hands-on experience in social entrepreneurship. Some SL research has suggested steps to develop better partnerships with communities [37]. The importance of understanding the local context and developing partnerships between universities and local community organizations has also been examined [38]. Researchers have also talked about the role of directors of local nonprofits [39]. These partnerships are important because they lay the foundation for social entrepreneurship [40]. They help the students learn, practice, and communicate with community partners to start social entrepreneurship. Since 2014, we have offered different SL courses in STEM education [41]. We have taught technologies, such as virtual reality [42], [43], computer vision, ML [44], and gesture detection [45] to our university students and help different disadvantaged groups. This approach has given our students valuable experiences beyond the traditional classroom setting.

III. Methodology

A. Proposed Teaching and Learning Cycle

Fig. 1 illustrates our envisioned teaching and learning cycle, an integration of SL principles with the 5E instructional model rooted in constructivist teaching. This integration forges a dynamic educational framework, particularly designed for STEM education, strongly emphasizing real-world application and community engagement. At the core of this cycle are three fundamental components of SL: academic study, practical experience, and community involvement, each contributing to a part of 5E elements in the educational journey.

The academic study phase forms the bedrock of the cycle, where students acquire theoretical knowledge that is essential for their subsequent practical applications. This foundational phase is crucial as it provides students with the necessary theoretical frameworks and scientific principles to guide their hands-on experiences. Progressing to the practical experience phase, students begin to actualize their theoretical knowledge into concrete skills, engaging in designing, developing, and deploying technical solutions that address real-world challenges. In the community involvement phase, the theoretical knowledge and practical skills merge within the context of community engagement. Students' solutions are implemented, allowing direct interaction with and impact on the community, thereby testing the viability of their solutions and enriching their understanding of societal needs.

Encircling these core elements is the 5E model, which delineates the overarching structure of the teaching and learning activities. Within this framework, the lecturer is vital in guiding students through the initial stages of engaging with and understanding client needs and potential solutions to a deeper exploration and elucidation of these concepts. The explain phase is of particular significance as the lecturer demystifies the technical solutions, correlating them to the community's needs during this phase.

Students are active participants in this learning process, deeply involved in a practical approach to education. Their active role in designing, developing and deploying solutions sharpens their technical knowledge and cultivates critical problem-solving and critical-thinking abilities. The iterative nature of the cycle is exemplified in the evaluation phase, which acts as a critical point of reflection. Client feedback during this phase is a valuable asset, offering insights into the effectiveness of the solutions and highlighting emerging needs. This continuous loop of feedback and improvement is pivotal for students to appreciate the real-world impact of their efforts.

In the explore stage, lecturers should actively engage with service recipients to comprehend their specific needs. For instance, in the context of an elderly home, lecturers should communicate with the home manager to ascertain the requirements that could enhance the daily lives of the elderly residents. Utilizing their expert knowledge, lecturers should envision how technical solutions can be adapted to address these needs effectively. This stage culminates with lecturers formulating a clear vision of the techniques, such as AI and game development, that will be taught and applied in the project, alongside a well-defined plan for the desired outcomes.

Subsequently, lecturers must convey the client's needs and objectives for the technical products to the students. Lecturers must have a precise technical solution in mind before instructing students, ensuring that the project remains aligned with the initial objectives. Throughout this process, lecturers should maintain a leadership role, guiding the direction and focus of the project.

During the elaborate stage, students engage in lectures and class exercises designed to impart contemporary technical solution knowledge. Through various technical exercises, students will acquire the necessary skills to design and develop their own technical solutions to meet the project's objectives.

Students will deploy their technical solutions and monitor their performance after the design phase. Community involvement is integral at this stage, as clients will provide feedback on the solutions. Students must respond promptly to this feedback, making necessary adjustments to improve their solutions.

Finally, postimplementation, lecturers and clients will collaboratively evaluate the technical solutions' performance. Lecturers will then facilitate a group discussion with students to analyze observations and identify potential improvements. This reflective process allows students to document their critical reflections and any new needs identified during brainstorming sessions, setting the foundation for the next project cycle.

Through this iterative process, students engage in various technical exercises, refine their solutions based on feedback, and develop a heightened sense of social responsibility. The lecturer, serving as both educator and mentor, navigates students through the complexities of their projects, while the clients act as both beneficiaries and evaluators of the students' endeavors.

The culmination of this cycle enhances the capabilities of the social entrepreneur. Students emerge from this cycle with a well-rounded STEM education equipped with the necessary practical experience and empathetic insights to apply their expertise in a socially responsible way. As a result, the four skills, including empathy and caring for others, problem-solving skills, knowledge application, and sense of social responsibility of students, can be enhanced. They are prepared to tackle innovation and entrepreneurship challenges with a profound understanding of their societal role, ready to use their STEM knowledge for the greater social good. This cycle is thus not merely an academic exercise but a transformative journey toward effective social entrepreneurship, leading to sustainable and impactful solutions for the community.

B. *Our Course Setting and Intended Learning Outcomes*

Crafting a course setting for SL within STEM disciplines necessitates a deliberate and thoughtful academic structure. This structure must strike a careful equilibrium between scholastic aims and the actionable aspects of community projects, preserving the educational essence of the course. It is imperative that the course not deviate into a sole emphasis on community or business projects, which might detract from its educational objectives. Lecturers are tasked with outlining the core elements for student exploration, a crucial step in shaping the academic journey.

Formulating intended learning outcomes (ILOs) is paramount and marks the initial step in this process. These ILOs must be clear, quantifiable, and designed to connect STEM proficiency with the tenets of social entrepreneurship. Lecturers are responsible for highlighting the integration of values and frameworks, including environmental, social, and governance (ESG) principles and the United Nations sustainable development goals (SDG). The aim of these objectives is to furnish students with the capacity to apply STEM solutions to social challenges, thereby nurturing a culture of social responsibility and a spirit of innovation.

Incorporating students in the service design process empowers them to take ownership of community projects and their evaluation. This involvement serves as a formative experience in social entrepreneurship. Furthermore, it is essential to incorporate the concepts of ESG, SDG, and the various funding mechanisms from government and corporate social responsibility initiatives into the curriculum. These inclusions will enrich the educational experience, equipping students with a comprehensive understanding of how such frameworks can be leveraged in the pursuit of societal advancement through SL.

Our ILOs are designed as follows.

1) Articulate the impact of computing technology in social contexts and its potential contribution to addressing the needs of the underprivileged.
2) Demonstrate awareness of the impact of social privilege on technology adoption and usage.
3) Analyze complex issues in the service setting and design, implement and apply appropriate technological solutions to meet the needs of the target recipients.
4) Demonstrate empathy for people in need and a sense of civic responsibility, especially pertaining to the use, deployment, and impact of technology.

1) Exploring and Explaining Needs of the Clients: Fig. 2 illustrates our flow of thinking to set the technical solutions for teaching activities. First, pinpointing clients' needs, particularly those from disadvantaged backgrounds, is an essential yet intricate endeavor requiring high care and precision. These parts represent more than mere challenges; they are gateways for students to bring academic theories and methods to life within real-world scenarios. A slogan serves as a guiding light throughout the course, directing the creation of technical solutions and ensuring that all efforts are coherent with the overarching theme of social advancement. It should be concise, memorable, and potent enough to provoke action, contemplation, and a connection to the broader social impact.

Our client consists of individuals with moderate intellectual or emotional challenges who encounter notable obstacles within the job market posteducation. Often, they are relegated to sheltered workshops where they perform tedious, repetitive tasks for scant compensation. The heart of the problem is a dire need for a more rounded and hands-on training regimen that prepares them for more complex roles such as those within convenience stores.

Regrettably, the prevailing training environment suffers from a deficiency in patience and civility among trainers, which can negatively affect our clients' self-assurance. In response, there is a pressing need for a training program tailored to individuals' unique learning paces and styles, one that is immersive and engaging to sustain their interest.

An interactive training program based on active learning principles stands to bridge this divide. Such a program would enhance their skill set, boost their confidence, and broaden their employability prospects. This could, in turn, afford them the opportunity to secure more fulfilling employment, increase their earnings, and foster meaningful interactions within the broader community.

The end goal is the reintegration of our clients into society, not solely as laborers but as valued and self-confident members. Our defining slogan encapsulates this aim: "*Increase in ability leads to an increase in respect*." This statement does more than summarize our goal for social development; it affirms

Fig. 2. Flowchart for course setting process.

the inherent dignity associated with personal and professional development.

By emphasizing the creation of this central message, the course can maintain its focus on academic outcomes while also imbuing the students' work with a strong sense of purpose. This strategy ensures that the course is upheld as an academic pursuit with tangible societal impact, framed within the SL pedagogy designed to enrich both student learning and community welfare.

2) Exploring and Explaining Goal and Objectives of Technical Products: Establishing a definitive goal and formulating clear objectives guide students in this journey. They will partake in a cyclic process of designing, experimenting, and refining these solutions under their lecturers' tutelage.

Our goal is to develop an interactive training program for convenience stores. The goal consists of three objectives: more hands-on experiences, engaging interaction, and adaptable teaching. The technical solutions and theories are selected based on these three objectives.

a) *More hands-on:* A real-world simulation should be designed to ease the transition from a training setting to an actual workplace. This safe, controlled environment allows for repeated practice, which is essential for skill acquisition and confidence building [46].
b) *More engaging:* The program emphasizes intuitive communication to capture and maintain the clients' interest. This feature is particularly beneficial for training individuals with autism spectrum disorder, encouraging them to engage in dialogue and respond to customer inquiries naturally instead of using multiple-choice questions [47].
c) *More adaptive:* Sensory adaptation should be central to the program, integrating both physical and virtual elements to create a cohesive learning environment. This sensory integration helps tailor the experience to individual learning needs and paces to different special education needs.

These elements culminate in an interactive learning platform where clients can practice and hone their skills. By interacting with virtual customers and responding to a variety of scenarios, they can learn from their mistakes in real time, without the pressure of real-life consequences. The clear goal and objectives provide our students with clear guidance.

3) Exploring and Explaining Technical Solutions: This course's teaching and learning approach diverges markedly from traditional methods, embodying a "STEM with meaning" philosophy. Rather than teaching individual STEM elements in isolation, the course integrates them into a cohesive, purpose-driven educational experience that aligns with our goal and objectives. This approach emphasizes the application of technology to meet clear societal needs, and it engages students in selecting and utilizing suitable technologies to address these needs. It equips students to anticipate and respond to the evolving demands of technology and society.

a) *Level 1. Virtual reality and game development:* The program simulates a real-world environment through the use of virtual reality and game development technologies. This part forms the fundamentals of the interactive training program. Students can learn basic application development rule-based control in the development. Different from traditional game development and AI courses that only learn from data logs [48], [49], students are able to observe the needs of clients and adjust the AI and rule settings. Source code and exercises are provided for the students to learn object manipulation, level design, and event-driven programming. We adopted unity 3-D and HTC Vive in this part.
b) *Level 2. Chatbot and natural language processing:* Chatbots and natural language processing are needed to achieve intuitive communication. It departs from the conventional multiple-choice questions, fostering spontaneous verbal communication. Students can learn advanced data structures, such as finite state machines, to design the content during the development. They can also explore the large

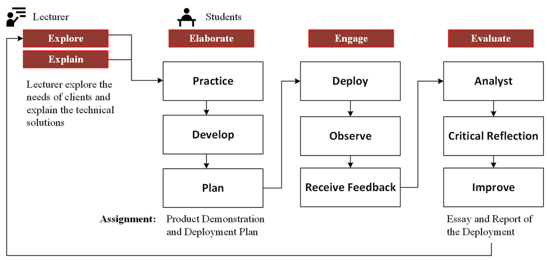

Fig. 3. Student role in the proposed Teaching and Learning (T&L) cycle.

language model and prompt engineering at this stage. We adopted Google Dialogdflow in this part.

c) *Level 3. Object recognition and computer vision:* Object recognition and computer vision technologies are employed to enhance the realism of the training, allowing clients to interact with a variety of products of convenience stores as they would in a real-world setting. Students can learn convolutional neural networks and advance computer vision technology. We adopted Google Vision in this part.

C. Implementation of the Proposed Teaching and Learning Cycle

Fig. 3 outlines the students' role in the remaining element of the 5E model. This process is cyclical, reflective, and geared toward continuous improvement.

In the explore and explain phase, lecturers introduce the course by exploring the client's needs and explaining potential technical solutions. As mentioned in previous sections, this sets the context for the learning activities and provides students with an understanding of the real-world problems they will be addressing.

Transitioning to the elaborate phase, students engage in hands-on activities, crafting their technical solutions, and outlining their deployment strategies. During this phase, they delve into the practical aspects of technical project development, learning, and practicing through the creation of tasks and content. Their work culminates in a product demonstration and a deployment plan, assignments that translate theoretical knowledge into tangible practice. At this juncture, students begin to form their own expectations regarding the technical products they develop.

In the subsequent engage phase, students put their technical solutions into practice within a real-world context, working alongside clients. Observing their solutions at work and collecting client feedback become pivotal components of the learning experience. During this phase, students often encounter a gap between their initial expectations and the reality of how their solutions perform.

The evaluation phase prompts students and lecturers to jointly review the outcomes, critically reflecting on the variances between anticipated and actual results. Students are prompted to pinpoint opportunities for enhancement, propelling them into a cyclical refinement process aimed at honing their solutions. An analytical essay and a comprehensive deployment report are expected deliverables, encapsulating the entirety of the student's

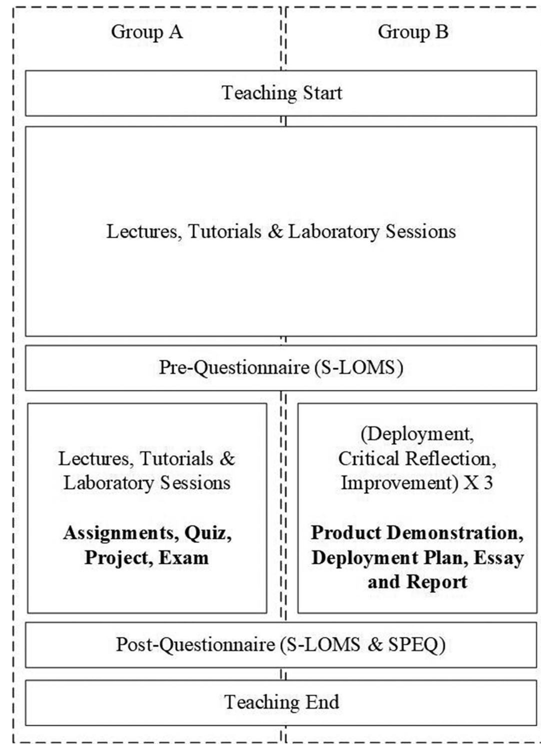

Fig. 4. Experiment setup.

educational journey, underscoring the applied technical aspects, and documenting the cyclical nature of their learning [50], [51], [52].

Lecturers are responsible for collecting these reflective essays and reports. Furthermore, they should provide additional resources to students to bolster their technical products, thereby initiating a new cycle of the teaching and learning process. In our experience, we have iterated through this teaching and learning cycle thrice .

This pedagogical framework guarantees that students not only acquire technical expertise but also cultivate the critical capacity to evaluate and enhance their work iteratively. This educational approach embodies "STEM with meaning," emphasizing the application of an integrated STEM curriculum to address authentic needs rather than treating STEM subjects as isolated academic units. The cycle demonstrates that the practical aspects of technical development frequently deviate from theoretical expectations, and it is through continual evaluation and adaptation, that students and lecturers can reconcile these differences.

IV. Experiment Setup

A quasi-experimental study design will be employed to evaluate the effectiveness of the teaching and learning cycle compared to traditional pedagogical approaches in university-level technology courses. As shown in Fig. 4, this study will include two groups of students. The study will include two groups of students: Group A, the comparison group, will receive conventional lecture-based instruction, while Group B, the experimental group, will participate in a curriculum structured around the proposed teaching and learning cycle. The students are in their third and fourth years at the University of Computing and are free to select their subjects. To address potential inequalities in access to technology or prior technical knowledge, we have added content, including self-learning materials and source code, for all students. The same lecturer will facilitate both groups to ensure consistency in delivery. However, it is important to note that the absence of random assignment, with students self-selecting into the groups, limits the rigor of the design and may introduce bias. This limitation should be considered when interpreting the results. The study aims to examine the impact of these different educational methods on student outcomes, particularly in game development, extended reality (XR), and natural language processing. These courses also introduce topics related to the game industry, educational games, entrepreneurship, ESG, and SDG.

Both the comparison and experimental groups will learn about up-to-date technologies, such as AI and XR. The experimental group will additionally learn to combine natural language processing with XR to develop a VR program for special educational needs (SEN) students and elderly individuals with dementia. This program includes a virtual character with a chatbot to help SEN students practice job skills for convenience stores and provide cognitive engagement for dementia patients. All students from the Department of Computing meet course prerequisites to ensure equal technical knowledge, facilitating a balanced evaluation of the specialized module's effectiveness in addressing the needs of these vulnerable populations.

Data collection for the study will be conducted using two main questionnaires. The first questionnaire will be administered at the semester's midpoint, following the coverage of essential technological concepts. At this juncture, neither group will have undergone any formal assessments, ensuring that their learning can be evaluated without the influence of graded assignments or tests. This questionnaire captures the students' perception of abilities regarding the foundational technology principles delivered through lectures, tutorials, and lab sessions.

Subsequently, the comparison group (Group A) will continue with traditional instruction and will be assessed through assignments, quizzes, projects, and examination. Conversely, the experimental group (Group B) will immerse themselves in the teaching and learning cycle without traditional lectures or related activities. Instead, they will focus on deploying, reflecting, and refining technical solutions. This cycle will be iterated three times, with assessments for Group B adjusted to include product demonstrations, deployment plans, essays, and reports.

A second questionnaire will be administered at the end of the semester to assess the student's perception of synthesizing and implementing advanced concepts and skills acquired during the course. The comparison of midsemester and end-of-semester questionnaire responses will enable an analysis of individual learning progression within groups and the relative effectiveness of the two teaching approaches across groups.

The selected instruments for assessing student learning outcomes are the student self-assessed learning outcomes from service learning (S-LOMS) and the student postexperience questionnaire (SPEQ). These tools facilitate self-evaluation by students regarding their learning gains and the overall experience. Notably, specific sections of these instruments, which are particularly designed for SL courses, have been excluded from this study. Only the generalized sections applicable to both traditional teaching and learning cycle methodologies have been retained for this comparative analysis.

1) Student Self-Assessed Learning Outcomes From Service Learning (S-LOMS): Our prequestionnaire is the S-LOMS [53]. It is a tool designed to evaluate student learning outcomes in SL contexts. The S-LOMS questionnaire and the SPEQ questionnaires measure students' self-evaluation before and after the class. As one of the SL course's targets is to build confidence, social responsibility, empathy, and problem-solving skills—attributes not measurable by assignment scores—these questionnaires can help reflect whether students feel they have improved in these areas. This feedback indicates that we can enhance the course design in the future. By assessing changes in students' self-perceived abilities, empathy, and social responsibility, we can make informed adjustments to better achieve the course objectives and foster these essential skills. This instrument enables students to rate their competencies on a ten-point Likert scale, ranging from 1 (strongly disagree) to 10 (strongly agree), both before and after their learning experience. S-LOMS has undergone extensive validation within the local setting, demonstrating commendable criterion validity, test–retest reliability, and internal consistency, as evidenced [54]. In this study, S-LOMS assesses four learning domains: knowledge application (four items) and problem-solving skills (four items) for intellectual learning, empathy and caring for others (three items), as well as a sense of social responsibility (three items) for civic learning. Table I presents the structure of the S-LOMS instrument, which encompasses four distinct domains. Students must self-evaluate across all these domains before the assessment. Acknowledging the generalized framework of the questionnaire's items, which are suitable for a broad educational context and not solely for SL, the S-LOMS instrument will be administered to both the comparison and experimental groups, both before the commencement and upon the completion of the course.

2) Student Postexperience Questionnaire (SPEQ): Our postquestionnaires are the S-LOMS and the SPEQ. It is developed by the university's research team, is grounded in the existing literature, and is tailored to the context of SL subjects at the university [55]. Due to the nature of the comparison group (Group A), which consists of a non-SL course, the student experience of the SL programme section has been omitted. The remaining portion of the SPEQ focuses on self-reported learning gains. This section contains nine items designed to measure students' self-perceived attainment of intellectual (four items) and civic (five items) learning outcomes. Each item is rated on a ten-point Likert scale, with one indicating "very little" and seven indicating "very much." This adaptation ensures the questionnaire's relevance and applicability to both the experimental and comparison groups. Table II details the content of the SPEQ. This set of questions includes 16 items designed to evaluate students' self-perceived achievement in

TABLE I
SELF-ASSESSED LEARNING OUTCOMES FROM SERVICE-LEARNING (S-LOMS) SURVEY QUESTIONS CATEGORIZED BY DOMAINS

Domains	No.	Questions
Problem solving skills	1	I am able to solve challenging real-life problems.
	2	I feel confident in dealing with a problem.
	3	I feel confident in identifying the core of a problem.
	4	I often modify my strategies to solve a problem when the situation changes.
Empathy and caring for others	5	I care about others.
	6	I observe others' feelings and emotions.
	7	I consider others' points of view.
Knowledge application	8	I know how to apply what I learn in class to solve real-life problems.
	9	I know how to transfer knowledge and skills from one setting to another.
	10	I am able to apply/integrate classroom knowledge to deal with complex issues.
	11	I can make connections between theory and practice.
Sense of social responsibility	12	I believe that everybody should be encouraged to participate in civic affairs.
	13	I feel obligated to help those who are less fortunate than me.
	14	I believe that taking care of people who are in need is everyone's responsibility.

TABLE II
SPEQ SURVEY QUESTIONS CATEGORIZED BY DOMAINS

Domains	No.	Questions
Intellectual development outcome	1	Ability to apply knowledge and skill in real life.
	2	Ability to solve problems.
	3	Ability to think creatively.
	4	Ability to analyze issues from multiple perspectives.
	5	Ability to reflect on and learn from experience.
Social development outcome	6	Ability to establish good interpersonal relationships.
	7	Ability to work in a team for common goals.
	8	Respect for people with diversity.
Civic development outcome	9	Understanding community needs and resources.
	10	Commitment to creating a better society.
	11	Empathy for disadvantaged people.
Intrapersonal development outcome	12	Self-confidence.
	13	Commitment to continued self-improvement.
	14	Self-understanding.

learning outcomes. Specifically, it measures intellectual outcomes through four items and civic outcomes through five items.

3) Participants and Data Collection Procedure: Participants from both the comparison and experimental groups were requested to complete questionnaires before and after the instructional sessions. The courses under investigation, both of which pertained to the domain of game design and development, were delivered by the same instructor. The distinction between the two lay in the pedagogical approach employed; specifically, one course was conducted in accordance with the proposed teaching and learning framework, whereas the other followed a conventional methodology. The comparison group comprised 58 students, from which 38 valid responses were obtained ($N = 38$). Conversely, the experimental group consisted of 18 students, yielding seven valid responses ($N = 7$).

V. EXPERIMENT RESULT

Both experimental and comparison cohorts participated in the student feedback questionnaire (SFQ), a standardized method our university employs to collect student feedback about their educational experience. This feedback serves a dual purpose: it informs the development of teaching strategies and also provides a basis for evaluating educational effectiveness. Remarkably, the SFQ results for both groups were congruent, with each group achieving a score of 4.5 out of 5.0, placing them within the top 10–25 percentile of feedback scores at our university. However, a contrasting narrative is revealed upon reviewing the S-LOMS and the SPEQ results, which indicate notable differences in the learning outcomes achieved by each group.

A. S-LOMS Results

Given that each domain encompasses multiple questions, an initial step involves calculating the mean score for each domain, followed by the application of a paired *t*-test to ascertain the presence of statistically significant differences in scores before and after participation in the subject courses. Fig. 5 presents the findings for the comparison group (Group A) and experimental group (Group B), indicating an absence of significant differences across all domains. For Group A, specifically, the mean score for knowledge application exhibited a minor decrease from 5.9 to 5.8, and the score for problem-solving skills declined from 6.6 to 6.3. Furthermore, the domain of empathy and caring for others saw a slight reduction from 7.0 to 6.9, while the sense

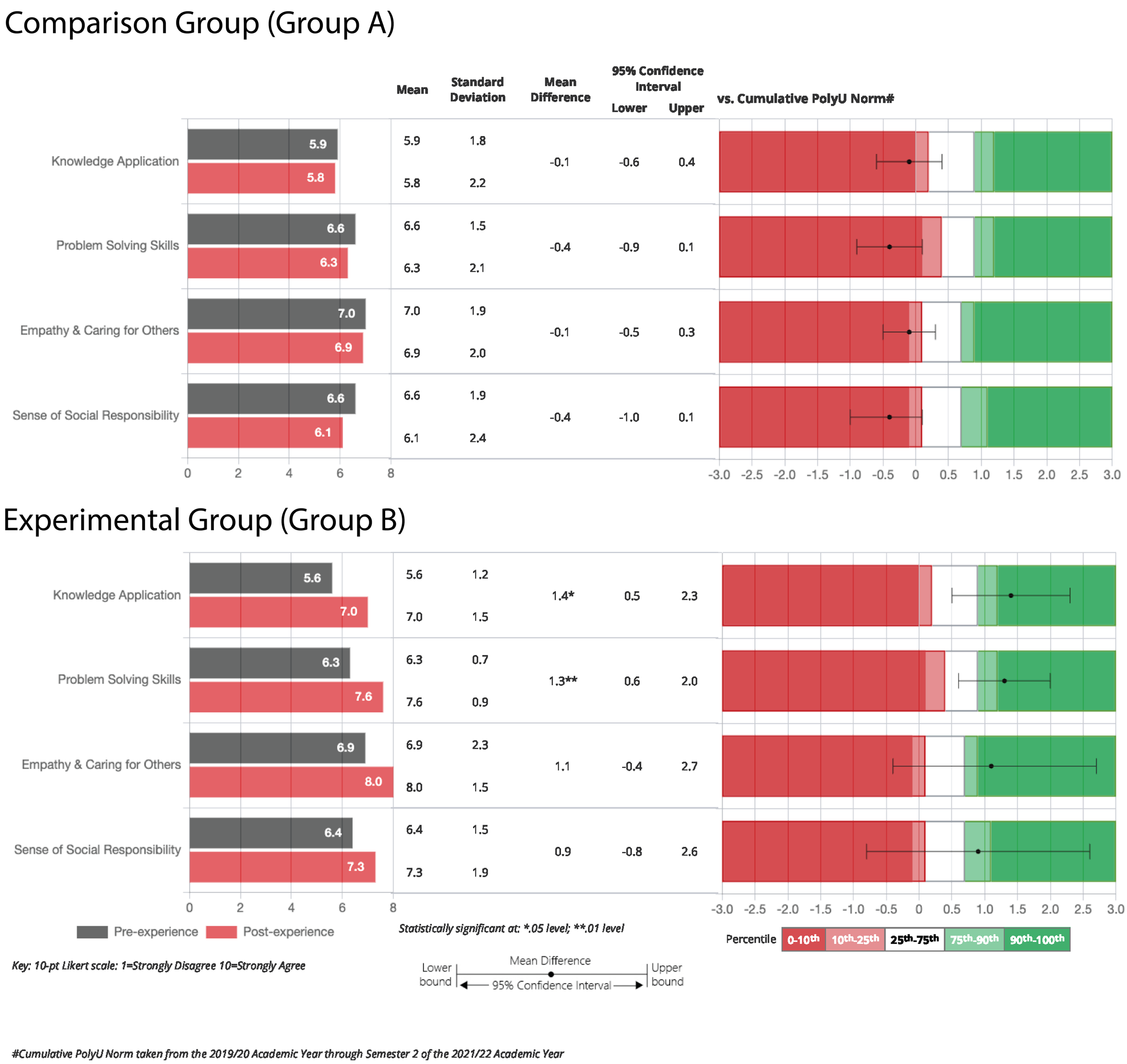

Fig. 5. S-LOMS results of two groups.

of social responsibility experienced a decrease from 6.6 to 6.1. Despite the lack of statistical significance between the pretest and posttest results, an overall downward trend in scores was observed in the S-LOME questionnaires. Moreover, the average scores fell below the 10th percentile compared to university norms.

Conversely, the experimental group (Group B) exhibited a general upward trend. Specifically, the knowledge application domain notably increased from 5.6 to 7.0, achieving statistical significance at 0.05. Similarly, the average score for problem-solving skills rose from 6.3 to 7.6, with this difference being significant at the 0.01 level. Although the null hypothesis could not be rejected for the domains of empathy and caring for others, and sense of social responsibility, both domains exhibited an increase in mean values, from 6.9 to 8.0 and from 6.4 to 7.3, respectively. The comparative analysis presented on the right-hand side of Fig. 5, juxtaposed with the cumulative University Norms, clearly reveals that students in the experimental group assessed themselves with relatively high scores, surpassing the 75th percentile.

B. SPEQ Results

Fig. 6 presents the findings from the intellectual development perspective of the SPEQ. The experimental group exhibits the highest percentage of 9–10 scores in the ability to analyze issues from multiple perspectives, whereas the comparison group shows the lowest percentage of 9–10 scores in this area. Furthermore, all five questions received a higher percentage of "Very Much" ratings in the experimental group compared to the comparison group. The average score for the comparison group is approximately 6.4, while the experimental group averages around 7.9.

Fig. 7 presents the findings from the social development outcome perspective of the SPEQ. In the experimental group, none of the questions received scores in the 1–5 range, indicating

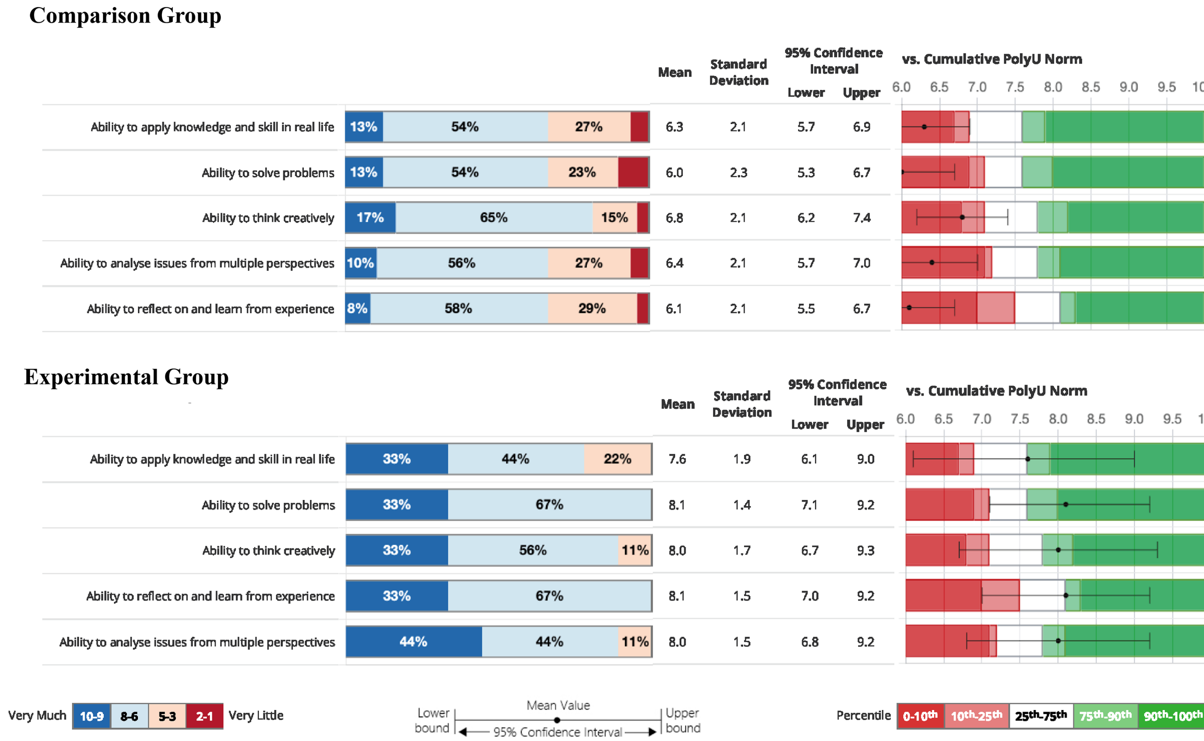

Fig. 6. SPEQ results of intellectual development outcome.

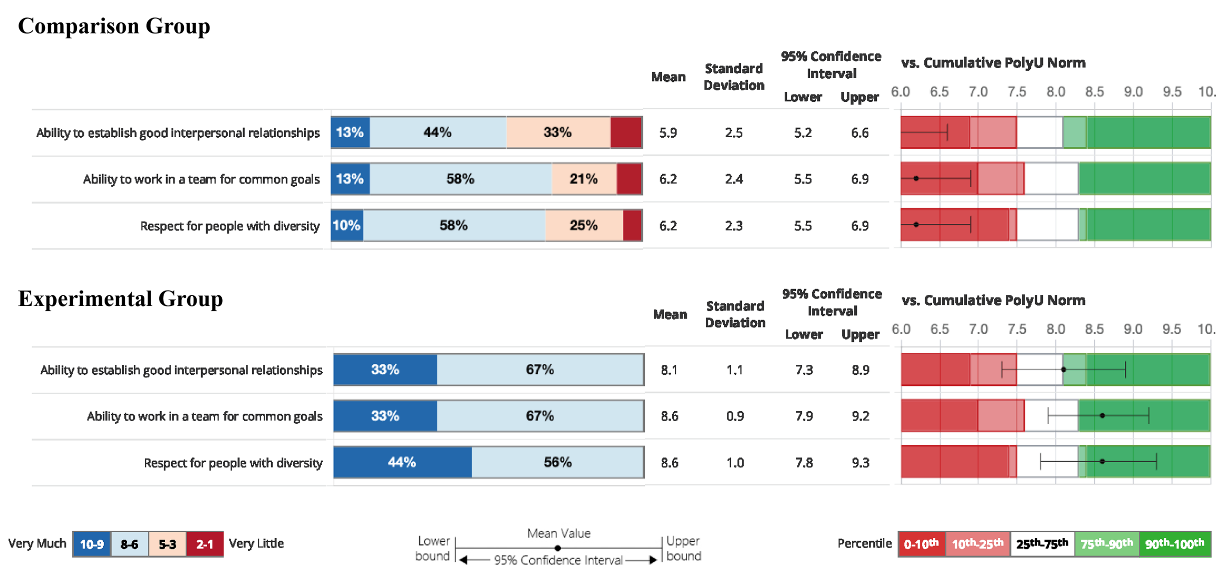

Fig. 7. SPEQ results of social development outcome.

consistently higher ratings across all assessed areas. Conversely, the comparison group exhibited more than 25% of responses in the 1–5 range for all questions, reflecting a lower overall performance in social development outcomes. The average score for the comparison group is approximately 6.1, whereas the experimental group averages around 8.3.

Fig. 8 shows the findings from the civic development outcome perspective of the SPEQ. The experimental group had over 50% 9–10 ratings for all three questions. The comparison group has around 10% with the highest rating and about 30% with ratings below 5 points. The average score for the comparison group is approximately 5.7, while the experimental group averages around 8.8.

Fig. 9 shows the findings from the intrapersonal development outcome perspective of the SPEQ. The overall scores for all three questions in the experimental group are higher than those in the comparison group. The average score for the comparison group is approximately 6.2, whereas the experimental group averages around 8.0.

The SPEQ findings predominantly concentrate on outcomes

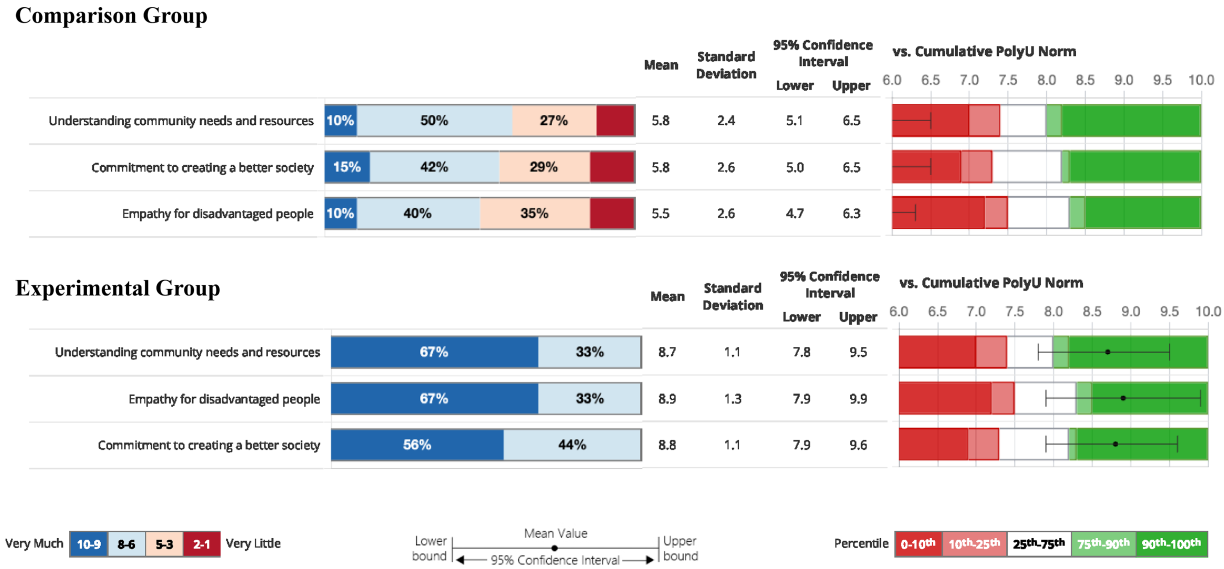

Fig. 8. SPEQ results of civic development outcome.

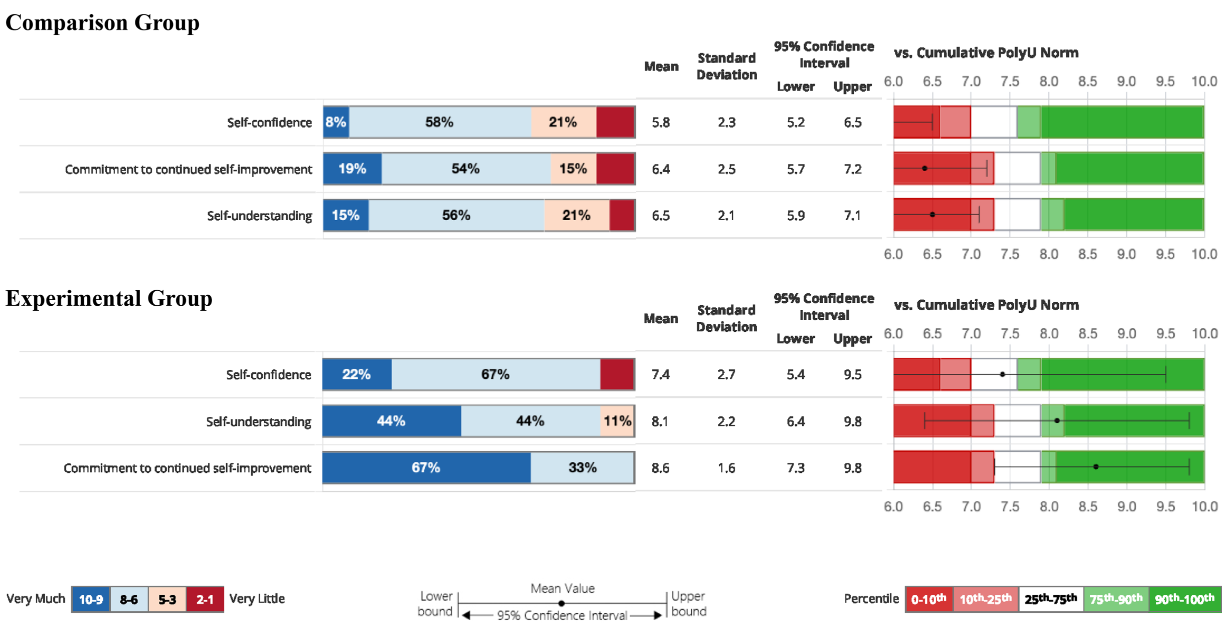

Fig. 9. SPEQ results of the intrapersonal development outcome.

related to intellectual development, social development, civic development, and intrapersonal development. The results pertaining to the comparison group (Group A) reveal that the majority of students did not achieve the anticipated learning outcomes satisfactorily. Notably, over one-quarter of the students reported a persistently low ability to apply acquired knowledge to practical development tasks. This pattern was mirrored across other evaluated domains, including social development, civic development, and intrapersonal development outcomes. Specifically, within the domain of civic development, more than one-third of the students rated their learning outcomes lower compared to those in the experimental group (Group B). When these outcomes are juxtaposed with the cumulative university norms, it becomes evident that the overall learning gains for the comparison group (Group A) are positioned below the 10th percentile across all subquestions.

The data from the experimental group (Group B) suggest that a majority of the students have enhanced their ability to forge meaningful social connections and have gained a deeper understanding of community needs. However, a minority reported relatively lower scores in their capacity to apply acquired knowledge to real-life situations. In addition, some students have reported a decrease in self-confidence subsequent to their participation in the subject courses. A comparative analysis with the cumulative university norms indicates that self-confidence scores are situated between the 25th and 75th percentiles, whereas the scores for other domains consistently exceed the 75th percentile.

VI. Discussion

A. Quantitative Insights From the Questionnaires

The findings indicate that students engaged in the proposed teaching and learning cycle exhibited an enhanced understanding of social relationships and increased civic awareness, particularly in terms of comprehending community needs. Conversely, students in the comparison group, who followed a conventional university curriculum, demonstrated a marked decrease in attention to social issues, which is expected. However, this group also reported lower confidence levels and limited ability to apply academic knowledge to real-life scenarios. This disparity may stem from the comparison group's restricted exposure to knowledge application, primarily within the confines of classroom settings and limited to academic projects. In contrast, students in the experimental group, who participated in the proposed teaching and learning cycle, were afforded opportunities to apply their learning in real-world contexts through SL experiences. This approach significantly bolstered their practical application skills and confidence, notably as they observed the tangible impact of their contributions to the community.

The multifaceted benefits of SL to students were further underscored through a comparative analysis with preceding studies employing identical questionnaires. Grace et al. [53] investigated students' SL experiences and outcomes, revealing an average score of approximately 5.5. In contrast, the outcomes from our postintervention questionnaires generally exceeded a mean value of 7. This disparity suggests that the framework we propose has the potential to significantly enhance students' learning and the acquisition of desired outcomes from their coursework.

The notable distinction observed in the results of the S-LOMS questionnaire underscores the substantial improvement in knowledge application and problem-solving skills among students who participated in the proposed teaching and learning cycle compared to those in the comparison group (Group A). Given their fundamental importance in initiating and successfully operating a business, these two skill domains may serve as crucial elements enabling students to embark on entrepreneurial ventures postgraduation.

The competencies of problem solving skills, empathy and caring for others, knowledge application, and sense of social responsibility are essential for a social entrepreneur. Our teaching and learning cycle has demonstrated significant advancements in cultivating these four core abilities in students. There was also a significant improvement in the experimental group (Group B) according to the pre-and postquestionnaires. Moreover, a significant difference exists between the comparison group (Group A) and experimental group (Group B) in the comprehensive set of skills, encompassing intellectual development outcomes, social development outcomes, civic development outcomes, and intrapersonal development outcomes. This multifaceted skill enhancement benefits social entrepreneurship and other entrepreneurial endeavors, underscoring the versatility and broad applicability of the skills acquired through our teaching and learning cycle. Our approach's effectiveness, particularly in teaching AI and ML, has surpassed traditional lecture-based settings, offering a more effective foundation for students aspiring to become entrepreneurs in any domain.

It is worth noting that findings suggest that both groups perceived a positive learning experience, indicating that students in university-level technology courses may receive a reasonably high-quality education when effective teaching quality control is in place. This perception of a positive learning experience could be attributed to the lecturer's competence, suggesting that the educator's expertise and teaching style significantly shape students' views of their education, regardless of the instructional method. These results highlight the importance of maintaining high teaching standards to ensure that students, whether in traditional or experimental learning environments, have a favorable and beneficial educational experience.

B. Qualitative Insights From the Experimental Group

A follow-up interview was conducted with students from the experimental group, highlighting a notable achievement: one team established a social enterprise dedicated to creating a virtual reality application to enhance verbal and cognitive skills in stroke patients. This venture is in the process of securing funding from Cyberport, a government-backed incubator in Hong Kong designed to support entrepreneurs and start-ups. Furthermore, the team has advanced to the semifinals of the Hong Kong Social Enterprise Challenge (HKSEC), a renowned competition for social enterprises in Hong Kong. As they articulated, their success stems not from serendipity but from the strong foundation laid during this course setting.

Key insights from the team underscored the importance of empathy and understanding, pivotal elements fostered by the course. It encouraged them to adopt the perspectives of others, leading to a critical realization during their project deployment: the necessity of integrating visual and auditory aids alongside textual instructions to accommodate the learning pace of clients with intellectual impairments. This adaptation transformed their training module into a more engaging and effective tool, underlining the power of empathy in creating impactful solutions.

Their journey from the course to developing a social enterprise for stroke patients exemplifies the seamless application of lessons learned, particularly in understanding end-user needs. Interactions with patients and professionals revealed a desire for more engaging rehabilitation methods than traditional practices offered. Responding to this feedback, they designed a conversational training application using Chatbots, addressing the resource constraints of human interaction. The trial phase was met with positive feedback, indicating the potential for broader applicability of these empathetic design principles, extending from product development to crafting marketing strategies and business models that resonate with investors. This narrative demonstrates the profound influence of SL experiences in equipping future social entrepreneurs with the skills to innovate and empathize effectively.

The skill of understanding and addressing user needs can be extended beyond application development to other aspects such as marketing strategies. By placing ourselves in the shoes of investors and comprehending their expectations and requirements, we were able to craft a competitive business model that attracted investor interest and invest in our social enterprise.

C. Adapting 5E Approach in Social Entrepreneurship Education

According to the social entrepreneurship [19], the 5E model approach primarily emphasizes the innovative-entrepreneurship, socio-entrepreneurship, and socio-visionary components. This model-oriented SL course provides students with a comprehensive understanding of social needs and human demands within underprivileged groups. It also lets students grasp how they might transform their technical solutions into future opportunities.

In addition, the course objectives, established by the lecturer, aim to deepen students' comprehension of how to apply their knowledge in real-world scenarios. This approach inspires innovation by allowing students to develop their own technical solutions within a well-defined framework, ensuring that their innovations remain within appropriate boundaries. Thus, the 5E model facilitates the practical application of theoretical knowledge and promotes creativity and problem-solving skills in the context of social entrepreneurship.

D. Distinguish SL From Internships

Students must be actively involved in designing, developing, and implementing service projects to distinguish SL from internships, volunteerism, or civic education. They should be granted autonomy over service deliverables, particularly in service design, to prevent misconceptions of SL as mere volunteerism [56]. The literature emphasizes that SL activities must stand apart from volunteer work. While Kenichi Ohmae's concept of the M-Form Society [57] has been referenced in broader discussions, there are anecdotal observations from students' reflective journals that suggest some may perceive SL as perpetuating a societal structure in which universities (the upper tier) encourage students (the middle tier) to assist disadvantaged groups (the lower tier). In this perception, while the upper class gains recognition and the lower class receive aid, the middle class provides time and resources without sufficient reward. To counter such misinterpretations, academic studies must clarify the unique value of SL as an integral part of social change.

E. Limitation

One of the primary limitations of this study stems from its quasi-experimental design, which, despite its strengths in practical educational research, introduces several constraints on the generalizability and control of variables. Although the comparison of both elective courses was meticulously conducted within the same university, under the guidance of the same lecturer, and with groups that achieved similar scores on the official SFQ, i.e., the grand mean of the items on the overall view scale was 4.5 out of 5.0, with a standard deviation of 0.7, and were exposed to similar materials, the difference in class size between the experimental and comparison groups presents a significant variable that could influence the outcomes. Also, a limitation of the study is that, although there is an experimental and a comparison group, the design lacks the rigor of a randomized controlled trial. Students were not randomly assigned to the groups, as those opting for the SL component were aware of the program they were entering. This lack of randomization introduces potential bias, which may influence the results.

The experimental group consisted of a small class setting of 18 students, whereas the comparison group comprised a medium-sized class of 58 students. This discrepancy in class size could inherently affect the dynamics of the teaching and learning experience. Smaller class sizes, such as the experimental group, often facilitate a more personalized learning environment, greater interaction between students and instructors, and more tailored feedback on student work. These factors can significantly enhance the learning experience and outcomes, potentially skewing the comparison with the larger comparison group.

The intimacy and increased engagement opportunities available in smaller classes might have contributed to the experimental group's enhanced outcomes beyond the impact of the innovative teaching and learning cycle alone. Therefore, while the findings suggest the effectiveness of the proposed pedagogical model, the influence of class size as a confounding variable cannot be overlooked. Future studies might aim to control for this factor more rigorously or explore its effects as part of the analysis to provide a clearer understanding of the pedagogical model's impact in varying educational settings.

Another notable limitation is the conversion from SL experience to real social entrepreneurship. Many students recognize social needs but are reluctant to transform their technical solutions into entrepreneurial ventures. This reluctance stems from the perception that these solutions cater to specific population needs, making generating profit and sustaining a social enterprise challenging. Consequently, students often view the SL experience as an eye-opening journey rather than a potential career path.

This observation suggests that university social entrepreneurship education should emphasize the entrepreneurial aspects. Educators should focus on teaching students how to develop profitable business models that can support social entrepreneurship. This is also the missing ring in this project. This approach would help build students' confidence in making a living through social entrepreneurship, ultimately increasing the conversion rate from SL experiences to entrepreneurial endeavors.

Incorporating comprehensive entrepreneurship training within the SL curriculum can equip students with the necessary skills to identify market opportunities, develop sustainable business plans, and implement strategies for financial viability. By doing so, universities can foster a more profound commitment among students to pursue social entrepreneurship, bridging the gap between academic learning and real-world application. This enhanced focus on the entrepreneurial component can transform SL projects from mere educational experiences into viable, impactful social enterprises that address pressing societal needs while economically sustainable.

VII. Future Direction

In the future, research should focus on equipping students with the skills to generate profit, thereby increasing their willingness to pursue social entrepreneurship without fearing for their financial survival. Encouraging students to start ventures requires teaching them how to transform their technical solutions into profitable products. The next step involves integrating more business perspectives into the current curriculum, following the successful implementation of technical solutions in SL projects. Future research will examine whether incorporating business knowledge into education enhances the likelihood of students launching social enterprises based on the technical solutions they developed during their coursework.

VIII. Conclusion

This article has contributed to the education field by demonstrating the efficacy of an innovative teaching and learning cycle in enhancing social entrepreneurship education, particularly through integrating AI and ML within a STEM framework. Our findings clearly indicate that students participating in this cycle not only gain a deeper understanding of social relationships and civic awareness but also exhibit considerable improvements in applying academic knowledge to real-world contexts, surpassing the outcomes of traditional teaching methods.

For educators interested in adopting this approach, it is crucial to focus on setting clear goals and designing technical solutions that students can effectively apply in real-world situations. Educators must remember that they serve as the leaders of the entire project, guiding the direction and maintaining alignment with the objectives.

The comparative analysis, employing pre- and postintervention questionnaires, revealed that our approach significantly enhances students' competencies in problem-solving, empathy, knowledge application, and sense of social responsibility. These competencies are crucial for anyone looking to make a meaningful impact through social entrepreneurship. The experimental group's performance, especially in applying AI and ML in tangible community projects, underscores the practical and versatile nature of the skills acquired.

We have adopted this model more than 12 times over the past ten years, ranging from small class sizes (fewer than 20 students) to large class sizes (more than 150 students). In addition, we have applied it to special education needs children and elderly learners. The main consideration has always been the needs of our clients, which we address during the exploration stage. Our study contributes to the broader discourse on entrepreneurship education by providing a scalable and replicable model that combines SL with the 5E constructivist teaching model. This model fosters a deeper engagement with STEM disciplines and cultivates a generation of students equipped to tackle societal challenges through innovative technological solutions.

Furthermore, the significant improvement in student outcomes, as evidenced by the S-LOMS questionnaire results, highlights the potential of this teaching and learning cycle to serve as a cornerstone for future curricular designs aimed at integrating technology education with social entrepreneurship. By surpassing traditional lecture-based educational outcomes, our approach offers a compelling argument for the adoption of more interactive, problem-based, and service-oriented teaching methodologies in higher education.

Finally, this article extends the pedagogical horizon, charting a course toward a more engaged, empathetic, and problem-solving-oriented educational ecosystem. Our contributions lay the groundwork for future research and implementation of educational models that are not only technically rigorous but also socially responsive, preparing students not just for careers but also for roles as change makers in an increasingly complex and interconnected world.

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