MODESTUM
EURASIA Journal of Mathematics, Science and Technology Education, 2024, 20(12), em2549
ISSN:1305-8223 (online)
OPEN ACCESS
Review Article
https://doi.org/10.29333/ejmste/15705

STEM service learning in higher education: A systematic literature review

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Received 11 March 2024 ▪ Accepted 08 June 2024

Abstract

In recent years, the adoption of service learning (SL) as a pedagogical strategy has gained momentum in higher educational institutions. This study aims to provide a comprehensive literature review on implementing SL in higher education, specifically in science, technology, engineering, and mathematics (STEM) education. The review processes included the dataset from Scopus and Web of Science. The final study included 20 articles based on the inclusion and exclusion criteria that were predetermined earlier. The findings of the study reveal the acceptance and use of SL in STEM education. The study looks into the uniqueness of previous STEM education SL frameworks. The benefits of STEM education SL for students are also identified. Lastly, the study highlights emerging issues regarding integrating STEM education and SL. In conclusion, the study provides valuable insights into the implementation of SL in higher education, particularly in STEM fields, by examining frameworks, benefits, and emerging issues in integrating this pedagogical approach.

Keywords: framework, STEM, SL, higher education, systematic literature review

INTRODUCTION

The state of our environment today is a matter that worries society. Regarding this, the UN General Assembly has come up with the 2030 agenda, which is made up of 17 sustainable development goals (SGDs) meant for the promotion of development (UN, 2015). It underscores the importance of mainstreaming education for sustainable development (ESD) into science, technology, engineering, and mathematics (STEM) education. In this integration, this should encourage the espousal of sustainable values and the fostering of stewardship. To effectively achieve this, vital strategies are essential for engaging students and providing learning experiences. This enhances environmental awareness and contributes to public service, including sustainable development. However, limited participation constrains the impact of many environmental education programs, often failing to yield meaningful engagement. New citizenship, encompassing philanthropy and personal responsibility, is vital in universities. To foster this, teaching must balance theory and practice (Camilleri, 2017), prompting the use of service learning (SL) to bridge students' knowledge-skill gap and enhance meaningful contribution (Martin, 2015). SL integrates theory, creativity, and social commitment, enabling students to apply knowledge and to improve their environment (Nguyen, 2023). Thus, SL becomes an essential strategy for sustainable development in education (Aramburuzabala & Cerrillo, 2023; Martín-Sánchez et al., 2022).

Recent years saw heightened academic interest in SL, driving proposed SL integration in higher education (Geller et al., 2014). Mayer et al. (2018) suggest enhancing STEM courses by raising awareness of interdisciplinary aspects and fostering community engagement. Other than that, approaches like assigning credit hours or participating in research combine learning with community service, globally enriching understanding, and practical application (Taggart & Crisp, 2011). In research, the benefits of SL have been emphasized, including enhanced learning outcomes and greater student involvement (Geller et al., 2014; Taggart & Crisp, 2011). It also contributes to levels of satisfaction within institutions and enhances civic knowledge (Rutti et al., 2016).

Additionally, SL helps with responsibility and develops crucial leadership skills (Afzal & Hussain, 2020). Furthermore, SL promotes the relevance of

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Contribution to the literature

- The research provides valuable insights into the acceptance, benefits, and challenges of integrating Service Learning (SL) in STEM higher education, and highlights how SL can improve students' skills, critical thinking, and sustainability awareness.
- The study highlights the necessity of incorporating all five elements of STEM SL for educators to develop a holistic STEM education, enhancing students' technical knowledge, essential skills, critical thinking, and readiness for success in the evolving STEM fields.
- The research underscores the importance of overcoming barriers to effectively implement service learning (SL) in STEM education. Addressing these challenges proactively allows educators and researchers to improve the quality, reliability, and impact of SL initiatives, facilitating more effective and sustainable integration of SL practices in academic environments.

classroom content, deepens understanding, and encourages the application of knowledge in different ways. This approach extends to STEM education, where students actively participate in projects that cultivate essential skills for sustainable development (Selco & Habbak, 2021).

Implementing SL poses challenges despite its benefits. These challenges encompass resource limitations, resistance from faculty and students, and complexities in evaluating the impact of such programs. Given universities' financial burdens, some may perceive STEM SL initiatives as expenses (Bennett, 2016). Educators might need more time to incorporate SL due to time constraints and concerns about aligning it with the existing curriculum (Ziegert & McGoldrick, 2008). Similarly, students often resist participation due to workload pressures (Yusop & Correia, 2013). Accurately assessing these programs' value in learning outcomes and their impact on communities is a task. Implementation necessitates meticulous planning that addresses barriers like funding limitations, educators' hesitancy, student disengagement, and the intricate nature of evaluating these initiatives. Prioritizing quality control throughout all phases is vital before scaling up these programs within universities.

Despite the increasing popularity of SL in higher education, further exploration and comprehensive systematic literature reviews are still needed to explicitly focus on its role in STEM education (Kaliisa & Picard, 2017). Consequently, this study aims to bridge these gaps by investigating the prevalence of STEM in higher education, examining the framework's components utilized in the previous study and its advantages for students, and addressing emerging issues of previous existing research on STEM SL in higher education.

METHODOLOGY

Formulating Research Questions

Two sources were used to create the research question: first, concepts from earlier studies focused on the STEM education SL framework in higher education; second, using the mnemonic of PICo, which signifies 'P' (population or problem), 'I' (interest), and 'co' (context). Based on these concepts, the authors included three main aspects as part of the review: STEM education (population), SL (interest), and higher education (context). The present study seeks answers to three major research questions about SL in higher education. The following inquiries need to be addressed:

(a) How extensively is SL incorporated into STEM education?

(b) Which STEM education SL framework components are utilized in the study, and what advantages does it offer students?

(c) What are the emerging challenges in STEM SL in higher education?

Following preferred reporting items for systematic reviews and meta-analysis using (PRISMA) statement (Liberati et al., 2009), we conducted a systematic review to address knowledge gaps by examining existing research. Our study aimed to fill these gaps by systematically exploring STEM SL literature to answer our research questions (Moher, 2019). This review followed defined methods to identify, select, and evaluate relevant research, synthesizing findings precisely and reliably (Moher, 2019).

Searching Strategy

Several search techniques were used to find pertinent research papers to meet the study's objectives. For our research, we utilized recognized and trusted databases such as Web of Science, Scopus, and Google Scholar to find relevant information in our field. We conducted searches on each database using keywords like "SL", "SL in higher education ", "SL frameworks ", "online SL," and "experiential learning" during initial search phase.

We searched each database individually with these keywords to ensure coverage of STEM SL studies. Our research selection criteria prioritized peer-reviewed journals to guarantee the reliability and validity of the information we gathered, as journals are widely regarded as sources of scientific information.

Selection Criteria

Systematic and rigorous selection criteria are established to ensure the selection of research that is most relevant to STEM SL. During the initial electronic database search, we restricted the scope of the literature search to a specific set of criteria. The term was only from 2010 to 2023, and the language was limited to English, with a "peer-reviewed articles" study type. We searched from 2010 to 2023 to gather a range of data. This allowed us to understand the nature of STEM SL, analyze the existing theoretical frameworks, and explore potential advantages of incorporating SL in STEM education. To ensure relevance of our findings, we focused on selecting studies that fulfilled one or more of the criteria:

(a) focused on designing and implementing STEM education SL,

(b) highlighting frameworks of STEM education SL,

(c) integrating service-learning components of STEM education courses or modules, including traditional and online education mediums, and

(d) on the outcomes and benefits of STEM education SL for students.

Study Selection and Data Obtaining

Selecting studies is a critical aspect of systematic literature reviews where factors such as inclusion criteria influence this process (Moher, 2019; Salam et al., 2017). To ensure study integrity, we followed Moher's (2019) guidelines stages: identification, screening, eligibility, and final inclusion decision based on study goals.

Our initial search yielded 547 articles from three databases: Web of Science and Scopus. After undergoing the identification phase, 468 articles were excluded due to being published in 2012 and earlier, published in the form of a chapter in a book, a book's conference proceedings, published in non-English, and non-availability of online full-text documents yielded 79 unique articles. After removing eight duplicate articles, the full-text articles assessed for eligibility total 71. Following title, abstract, and content screening, 51 articles were excluded because the studies did not focus on STEM SL in the higher education setting and the studies did not operationalize the STEM SL framework. Ultimately, we selected 20 articles included in the qualitative synthesis. Overview of search protocols for systematic literature searches based on Moher (2019) guidelines who PRISMA as presented in **Figure 1**.

The data was obtained using a cross-database approach to enhance the range, diversity, and extent of information in the included studies related to STEM SL in higher education. The summarize of the data obtained is presented in **Table 1**.

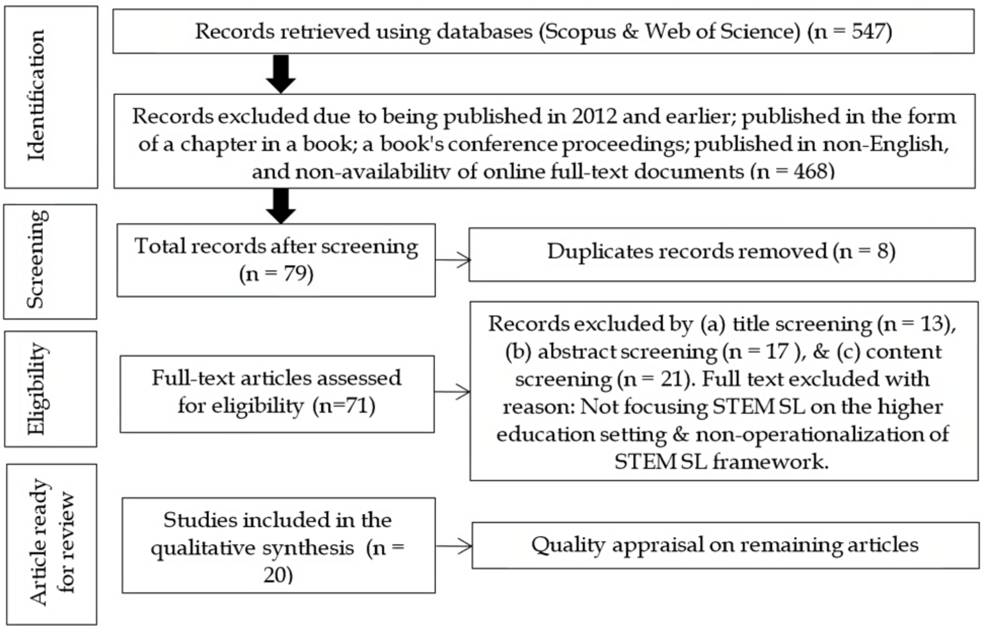

Figure 1. Flow diagram of the search process (Source: Authors' own elaboration)

Table 1. Descriptive information on the included study from Scopus and Web of Science

Sources	Scopus	Web of Science
Main information		
Final data screening (articles)	49	22
Study excluded		
By title screening	11	2
By abstract screening	15	2
By content screening	10	11
Total	36	15

Table 1 (continued). Descriptive information on the included study from Scopus and Web of Science

Sources	Scopus	Web of Science
Full text excluded with reason		
Not focusing STEM SL on higher education	7	6
Non-operationalization of STEM SL framework	3	9
Final study include	13	7

Table 2. Results of the quality assessment

Study	Research design	Q1	Q2	Q3	Q4	Q5	n	IR
Bielefeldt and Canney (2015)	Mixed-methods	/	/	/	x	/	4/5	√
Smith et al. (2021)	Qualitative research	/	/	/	/	/	5/5	√
Branker et al. (2010)	Mixed-methods	x	/	/	x	/	3/5	√
Derreth and Wear (2021)	Qualitative research	/	/	/	/	/	5/5	√
Adkins-Jablonsky et al. (2021)	Qualitative research	/	/	/	/	/	5/5	√
Brown and Bauer (2020)	Mixed-methods	/	/	/	x	/	4/5	√
Canney and Bielefeldt (2015)	Qualitative research	/	/	/	/	/	5/5	√
Namasivayam and Moganakrishnan (2018)	Qualitative research	/	/	/	/	/	5/5	√
Hernández-Barcoet al. (2020)	Qualitative research	/	/	/	/	/	5/5	√
Mostafavi et al. (2016)	Qualitative research	/	/	/	/	/	5/5	√
Qu et al. (2020)	Quantitative research	/	/	/	/	/	5/5	√
Page and Stanley (2014)	Mix-method	/	/	/	x	/	4/5	√
Birzer and Hamilton (2019)	Quantitative research study	/	/	/	/	/	5/5	√
Naik and Bandi (2023)	Mix-method	/	/	/	x	/	4/5	√
Smith et al. (2018)	Quantitative research	/	/	/	/	/	5/5	√
Børsen et al. (2020)	Qualitative research	/	/	/	/	/	5/5	√
Phang et al. (2021)	Qualitative research	/	/	/	/	/	5/5	√
Appiah-Kubi et al. (2019)	Quantitative research	/	/	/	/	/	5/5	√
Ngo and Chase (2020)	Quantitative research	/	/	/	/	/	5/5	√
Mclean et al. (2019)	Qualitative research	/	/	/	/	/	5/5	√

Note. n: Number of criteria fulfilled & IR: Inclusion in the review

Hong et al. (2018) created the mixed-method appraisal tool (MMAT), which enables researchers to evaluate a systematic mixed-methods review and encompasses five distinct types of studies: qualitative research, randomized controlled trials, non-randomized studies, quantitative descriptive studies, and mixed-methods studies. Before conducting the quality assessment, each study went through two screening procedures. In this step, we evaluated the chosen studies based on five criteria outlined in the research design. These criteria included assessing the effectiveness of data generation and adequacy of data collection. The primary author and co-authors meticulously examined the methodology and analysis sections to ensure analytical soundness. Including articles in our review had to meet a minimum of three criteria according to MMAT standards. Consensus-based decisions were made, and any disagreements were resolved through discussion. All selected studies fulfilled the requirements for methodology and analysis by meeting three out of five criteria (Hong et al., 2018). We identified fifteen articles that met all criteria, four articles that met four criteria, and another article that met three criteria (**Table 2**).

RESULTS

This section examines how extensively SL is incorporated into STEM in higher education, including in real settings and online platforms. As a result, this section answers our research question, "To what extent are SL adopted across different disciplines in STEM higher education?" To address this query, we delved into a study that examines the incorporation of SL into education in STEM fields. The findings from this study revealed that engineering disciplines have adopted SL in their courses (n = 17), and it forms 85% of the selected study, while science (n = 3) forms 15%.

The second question is the response to the elements of the STEM education SL framework utilized in the present study and their benefits to students. It is noteworthy that 15 studies incorporated all five elements of SL, such as community engagement, collaborative learning, curriculum integration, technology integration, and reflection (Adkins-Jablonsky et al., 2021; Appiah-Kubi et al., 2019; Branker et al., 2010; Brown & Bauer, 2020; Derreth & Wear, 2021; Hernández-Barco et al., 2020; Mclean et al., 2019; Mostafavi et al., 2016; Naik & Bandi, 2023; Ngo & Chase, 2020; Page & Stanley, 2014; Qu et al., 2020; Smith et al., 2018). While three studies only report using four elements out of five of the SL framework (Namasivayam & Moganakrishnan, 2018; Phang et al., 2021; Smith et al., 2021). Other than that, the rest of the study only reports using two elements of the SL framework: community engagement and curriculum integration (Bielefeldt & Canney, 2015) and community engagement and reflection (Canney & Bielefeldt, 2015).

Table 3. Elements of STEM SL framework applied

Author	Framework				
	CE	CL	CI	TI	Reflection
Bielefeldt and Canney (2015)	/	NA	/	NA	NA
Smith et al. (2021)	/	/	/	NA	/
Branker et al. (2010)	/	/	/	/	/
Derreth and Wear (2021)	/	/	/	/	/
Adkins-Jablonsky et al. (2021)	/	/	/	/	/
Brown and Bauer (2020)	/	/	/	/	/
Canney and Bielefeldt (2015)	/	NA	NA	NA	/
Namasivayam and Moganakrishnan (2018)	/	/	/	NA	/
Hernández-Barcoet al. (2020)	/	/	/	/	/
Mostafavi et al. (2016)	/	/	/	/	/
Qu et al. (2020)	/	/	/	/	/
Page and Stanley (2014)	/	/	/	/	/
Birzer and Hamilton (2019)	/	/	/	/	/
Naik and Bandi (2023)	/	/	/	/	/
Smith et al. (2018)	/	/	/	/	/
Børsen et al. (2020)	/	/	/	/	/
Phang et al. (2021)	/	/	/	/	NA
Appiah-Kubi et al. (2019)	/	/	/	/	/
Ngo and Chase (2020)	/	/	/	/	/
Mclean et al. (2019)	/	/	/	/	/

Note. CE: Community engagement; CL: Collaboration learning; CI: Curriculum integration; & TI: Technology integration

The STEM service-learning framework elements applied in selected studies summarized in **Table 3**.

The study's findings highlight a range of positive outcomes stemming from SL in STEM higher education. These outcomes encompass the development of essential soft skills and professional competencies, such as improved communication skills (Adkins-Jablonsky et al., 2021; Appiah-Kubi et al., 2019; Ngo & Chase, 2020), promotion of teamwork and collaboration (Birzer & Hamilton, 2019; Ngo & Chase, 2020), enhance of critical thinking and problem-solving abilities (Birzer & Hamilton, 2019; Naik & Bandi, 2023; Smith et al., 2021), promote leadership qualities and self-directed learning, (Birzer & Hamilton, 2019; Naik & Bandi, 2023; Phang et al., 2021), and cultivate emotional intelligence and cultural sensitivity (Birzer & Hamilton, 2019; Ngo & Chase, 2020; Phang et al., 2021).

Furthermore, SL contributes to an increased understanding and awareness of sustainability issues, including the promotion of sustainable development practices and ethical decision-making (Børsen et al., 2020), integration of sustainability concepts into engineering education (Ngo & Chase, 2020), enhancement of personal and professional responsibility for sustainability (Adkins-Jablonsky et al., 2021; Ngo & Chase, 2020), and improvement of knowledge and behaviors related to sustainability (Hernández-Barco et al., 2020; Naik & Bandi, 2023; Namasivayam & Moganakrishnan, 2018; Qu et al., 2020; Smith et al., 2018). Moreover, SL offers real-world experience and practical skills by providing hands-on opportunities to solve real-world problems (Birzer & Hamilton, 2019; Smith et al., 2018), fostering project management and technical skills demanded by the industry (Birzer & Hamilton, 2019; Mostafavi et al., 2016), promoting trans-disciplinary thinking and innovative problem-solving (Birzer & Hamilton, 2019; Naik & Bandi, 2023), and enhancing motivation and engagement in learning (Birzer & Hamilton, 2019; Branker et al., 2010).

The positive impact of SL extends to personal growth and development, evidenced by an increased sense of civic engagement and responsibility for public welfare (Adkins-Jablonsky et al., 2021; Bielefeldt & Canney, 2015; Phang et al., 2021), heightened self-awareness and personal identity (Adkins-Jablonsky et al., 2021; Ngo & Chase, 2020), promotion of positive attitudes toward change-making and social responsibility (Bielefeldt & Canney, 2015; Ngo & Chase, 2020; Phang et al., 2021; Smith et al., 2021), and the development of commitment and dedication to personal values (Ngo & Chase, 2020). Lastly, SL establishes connections with communities and offers international exposure, promoting cross-disciplinary work and global perspectives (Ngo & Chase, 2020; Phang et al., 2021), enhancing confidence and identity as engineers (Mclean et al., 2019), and fostering improved attitudes toward cultural awareness and tolerance (Birzer & Hamilton, 2019; Ngo & Chase, 2020). These diverse outcomes underscore the multifaceted benefits of integrating SL in STEM education. The STEM service-learning benefits are summarized in **Table 4**.

For the third research question, five challenges arise in integrating STEM SL in higher education: generalizability limitation, data limitation, methodological limitation, curriculum limitation, and impact limitation. The study's findings highlight issues in terms of generalizability. Researchers often faced difficulties due to sample sizes in their studies (Brown &

Table 4. The benefit of STEM SL to students

Outcomes of SL	Description	References
Development of soft skills and professional competencies	Improved communication skills	Adkins-Jablonsky et al. (2021), Appiah-Kubi et al. (2019), & Ngo and Chase (2020)
	Promotion of teamwork and collaboration	Birzer and Hamilton (2019) & Ngo and Chase (2020)
	Enhancement of critical thinking and problem-solving abilities	Birzer and Hamilton (2019), Naik and Bandi (2023), & Smith et al. (2021)
	Promotion of leadership qualities and self-directed learning	Birzer and Hamilton (2019), Naik and Bandi (2023), & Phang et al. (2021)
	Development of emotional intelligence and cultural sensitivity	Birzer and Hamilton (2019), Ngo and Chase (2020), & Phang et al. (2021)
Increased understanding and awareness of sustainability issues	Promotion of sustainable development practices and ethical decision-making	Børsen et al. (2020)
	Integration of sustainability concepts into engineering education	Ngo and Chase (2020)
	Enhancement of personal and professional responsibility for promoting sustainability	Adkins-Jablonsky et al. (2021) & Ngo and Chase (2020)
	Improvement of knowledge and behaviors related to sustainability-related issues	Hernández-Barco et al. (2020), Naik and Bandi (2023), Namasivayam and Moganakrishnan (2018), Qu et al. (2020), & Smith et al. (2018)
Real-world experience and practical skills	Hands-on experience in solving real-world problems,	Birzer and Hamilton (2019) & Smith et al. (2018)
	Development of project management and technical skills demanded by the industry	Birzer and Hamilton (2019) & Mostafavi et al. (2016)
	Promotion of trans-disciplinary thinking and innovative problem-solving	Birzer and Hamilton (2019) & Naik and Bandi (2023)
	Enhancement of motivation and engagement in learning	Birzer and Hamilton (2019) & Branker et al. (2010)
Positive impact on personal growth and development	Increased sense of civic engagement and responsibility for public welfare	Adkins-Jablonsky et al. (2021), Bielefeldt and Canney (2015), & Phang et al. (2021)
	Enhancement of self-awareness and personal identity	Adkins-Jablonsky et al. (2021) & Ngo and Chase (2020)
	Promotion of positive attitudes toward change-making and social responsibility	Bielefeldt and Canney (2015), Ngo and Chase (2020), Phang et al. (2021), & Smith et al. (2021)
	Development of commitment and dedication to personal values	Ngo and Chase (2020)
Connection with communities and international exposure	Promotion of cross-disciplinary work and international exposure	Ngo and Chase (2020) & Phang et al. (2021)
	Enhancement of confidence and identity as engineers	Mclean et al. (2019)
	Improvement of attitudes toward cultural awareness and tolerance	Birzer and Hamilton (2019) & Ngo and Chase (2020)

Bauer, 2020; Derreth & Wear, 2021; Ngo & Chase, 2020; Phang et al., 2021; Qu et al., 2020; Smith et al., 2018). Moreover, they encountered challenges such as the need for more comparisons with institutions or contexts (Page & Stanley, 2014) and a narrow focus on fields, courses, or institutions (Mclean et al., 2019; Qu et al., 2020; Smith et al., 2021). Another issue identified was the potential for biases in data collection processes (Canney & Bielefeldt, 2015).

Regarding data limitations, researchers faced obstacles due to confounding factors (Ngo & Chase, 2020), needing more information in the data (Adkins Jablonsky et al., 2021), and a limited range of initiatives or resources (Branker et al., 2010). There were some concerns regarding the limitations of the methodology used in the studies. These included a focus or scope in some studies (Appiah Kubi et al., 2019; Ngo & Chase, 2020; Phang et al., 2021; Qu et al., 2020; Smith et al., 2021, 2018) potential bias from researchers (Canney & Bielefeldt, 2015; Ngo & Chase, 2020) and a lack of a control group for comparison purposes (Ngo & Chase, 2020).

Additionally, there were challenges related to curriculum limitations. These challenges arose from constraints such as limited course time or resources (Branker et al., 2010) and difficulties in collaboration (Børsen et al., 2020). When considering the impact of integrating sustainability, it was observed that there was a lack of long-term follow-up in some studies (Branker et al., 2010; Naik & Bandi, 2023; Qu et al., 2020) as challenges in measuring sustained impact (Derreth & Wear, 2021; Naik & Bandi, 2023) (**Table 5**).

DISCUSSION

This review discovered that most STEM education research using SL (85% or 17) was conducted in engineering fields. The rest came from science disciplines. This can be attributed to engineering education's emphasis on practical application.

Table 5. Emerging issues of integrating STEM education in SL

Existing issues faced	Description	References
Generalizability limitation	Limited sample size	Brown and Bauer (2020), Derreth and Wear (2021), Ngo and Chase (2020), Phang et al. (2021), Qu et al. (2020), & Smith et al. (2018)
	Lack of comparison with other institutions or contexts	Page and Stanley (2014)
	Specific focus on a certain field, course, or institution	Mclean et al. (2019), Qu et al. (2020), & Smith et al. (2021)
	Potential biases in the data collection process	Canney and Bielefeldt (2015)
Data limitations	Confounding factors	Ngo and Chase (2020)
	Incomplete data or missing information	Adkins-Jablonsky et al. (2021)
	Limited range of available initiatives or resources	Branker et al. (2010)
Methodological limitations	Narrow focus or scope	Appiah-Kubi et al. (2019), Ngo and Chase (2020), Phang et al. (2021), Qu et al. (2020), & Smith et al. (2018, 2021)
	Potential researcher bias	Canney and Bielefeldt (2015) & Ngo and Chase (2020)
	Lack of a control group for comparison purposes	Ngo and Chase (2020)
Curriculum limitations	Limited course time or resources	Branker et al. (2010)
	Difficulty with interdisciplinary collaboration	Børsen et al. (2020)
Impact limitations	Lack of long-term follow-up	Branker et al. (2010), Naik and Bandi (2023), & Qu et al. (2020)
	Difficulty measuring sustained impact	Derreth and Wear (2021) & Naik and Bandi (2023)

Engineering students can directly apply their skills to real-world issues through SL, demonstrating the impact of their work on communities and society for development. In contrast, implementing SL in science education faces challenges in identifying community projects aligned with scientific content and providing suitable opportunities. Practical limitations arise from controlled environments and specialized equipment for experiments, making SL integration outside of labs difficult. SL's association with applied problem-solving disciplines like engineering or social sciences hinders its alignment with scientific inquiry. These factors contribute to lower SL adoption in science education.

Implementation of STEM SL Framework and Its Benefit

The STEM service-learning framework impacts the growth of students' interpersonal skills and professional abilities. It encompasses components, including community involvement, teamwork, learning, incorporating curriculum, integrating technology and reflection. Together, these elements create a rounded experience. Community involvement plays a role in this framework as it encourages students to engage in solving real-world problems (Mebert et al., 2020). Students understand societal needs by connecting with their communities and acquiring skills like effective communication, empathy, and cultural competency (Capella-Peris et al., 2020). This hands-on approach allows them to apply knowledge gained in classrooms to situations effectively, making their learning more meaningful and applicable.

Promoting collaboration and cooperative learning is another aspect that fosters teamwork skills among students. Through group projects and collaborative activities, students learn how to work with peers from backgrounds. They acquire communication, active listening, conflict resolution techniques, and negotiation skills. All of which are essential for successful collaboration both academically and professionally. Incorporating curriculum integration ensures that academic subjects are interconnected rather than taught in isolation (García & Longo, 2013). By integrating a variety of disciplines into STEM education through hands-on projects or activities that span subjects, students enhance their thinking skills while also developing the adaptability and creativity needed for problem-solving in various fields (Conradty et al., 2020; Dare et al., 2021).

The integration of technology is crucial in preparing students for the job market, where proficiency in technology is highly valued (Ghavifekr & Rosdy, 2015; Pradhananga & ElZomor, 2023). Using tools and incorporating coding or programming tasks into the curriculum, students acquire relevant skills that empower them to innovate and access information efficiently. On the other hand, reflection plays a role at every stage of this process-oriented teaching and learning approach. Encouraging self-reflection helps students identify their strengths and weaknesses, fostering a growth mindset that supports improvement (Kawai, 2021). Regular reflection encourages learners to use strategies that allow them not only to evaluate their progress but also to identify areas that require further development, ultimately enhancing their professional abilities (Bringle & Clayton, 2012).

Involving the community in STEM education impacts students' understanding and awareness of sustainability issues. The true power of such involvement lies in its ability to cultivate a strong sense of duty toward sustainability, equipping students with the necessary tools to confront future hurdles (Westskog et al., 2021). When STEM students actively participate in their local communities, they acquire invaluable practical experience (Mildenhall, 2021) and a profound appreciation for the significance of sustainable methodologies (Teslenko, 2019). Following Gamage et al. (2022), active involvement of the community in STEM higher education amplifies students' comprehension of sustainability dilemmas by providing tangible instances and hands-on encounters. This approach equips students with the knowledge and skills to make a genuine difference on the path to an enduring future. By supplementing traditional classroom instruction with practical application, students develop a deeper grasp of the significance of sustainability and its relevance to their chosen field of study (Zidny et al., 2020).

Community engagement initiatives pave the way for students to collaborate alongside professionals in their respective domains, granting them firsthand exposure to implementing sustainable practices across diverse industries. Moreover, integrating sustainability into pedagogical approaches is essential to ensure that students are well-equipped with knowledge concerning environmental concerns that can be addressed through scientific inquiry (Gamage et al., 2022; Otte, 2016). Through the purposeful integration of sustainability concepts into curriculum design, institutions take a proactive stance toward confronting global challenges like climate change and the depletion of resources. As STEM programs continue evolving, it becomes imperative to prioritize the incorporation of experiential learning opportunities related to environmental issues as part of endeavors aimed at achieving SDGs (Gamage et al., 2022).

Incorporating technology into STEM courses has enhanced student learning by allowing them to analyze and interpret complex sustainability data, leading to a deeper understanding of environmental challenges (Yang & Baldwin, 2020). The study conducted by Yang and Baldwin (2020), highlights the importance of using technology in an integrated STEM learning environment. These strategies can assist students in analyzing and interpreting complex sustainability data by providing authentic learning contexts, offering web-based inquiry environments, expanding learning through immersive and interactive technology, and transforming students from consumers to creators (Yang & Baldwin, 2020). These approaches contribute to a broader understanding of environmental issues critical to future generations. As modern societies increasingly rely on technological advances, educators must employ innovative teaching methods that foster scientific literacy while stimulating curiosity about global challenges such as climate change. As per Altomonteet al. (2016), information and communication technology-enhanced-based approaches can substantially contribute to the agenda of sustainability in higher education, primarily due to their accordance with interactive communication and contextualization of knowledge while guaranteeing flexible time and pace of learning. By leveraging the power of technology in STEM education, instructors can equip their students with the necessary tools to tackle real-world problems while also creating a passion for lifelong learning (Carstens, 2021).

Reflective practices in STEM higher education are essential as they promote critical thinking and problem-solving skills crucial for addressing sustainability issues (Alam, 2022). According to Gamage et al. (2022), integrating sustainability into learning and teaching in STEM programs is significant because it equips students with the knowledge, understanding, and skills to impact the journey toward a sustainable future. This approach prompts students to contemplate the broader consequences of their actions on society and the environment. STEM fields shape our world and have wide-ranging effects on health, equity, the economy, and the environment. Thus, incorporating reflective practices in STEM education can foster responsible behavior, instilling values like nature respect, ethical responsibility, social justice awareness, and critical thinking for sustainable problem-solving (Baporikar, 2021).

However, the research uncovered that only four studies examined technology as part of their approach to SL in STEM education. This suggests a need for more technology integration in SL despite its role in modernizing STEM education. The limited use of technology can be attributed to challenges such as funding that hampers hands-on experiences (Johnson et al., 2016), unequal access, which reduces practicality (Yusof et al., 2020), and the absence of standardized guidelines which hinders equitable implementation (Chen & Ma, 2014). To overcome these barriers, allocating funds ensures access to resources, and establishing clear and inclusive standards for integrating technology is crucial. Educators and institutions can shape a more inclusive and impactful future for STEM SL by addressing these challenges through teaching strategies.

Emerging Challenges of STEM SL in Higher Education

STEM SL research in higher education faces emerging challenges that necessitate effective resolution to integrate community engagement with academic curriculum successfully. These challenges encompass generalizability, data, methodology, curriculum, and impact limitations. Sample size limitations and a lack of comparison impede the generalizability of service-learning research due to small participant numbers and a focus on specific institutions, restricting broader representation (Brown & Bauer, 2020; Derreth & Wear, 2021; Ngo & Chase, 2020; Phang et al., 2021; Qu et al., 2020). Moreover, biases in data collection processes, such as self-selection bias, further undermine the reliability of findings (Canney & Bielefeldt, 2015). Data limitations, including confounding factors, incomplete information, and restricted availability of initiatives and resources, also impact the reliability and validity of research outcomes (Jager et al., 2008). To overcome these limitations, it would be advantageous for researchers to involve a group of students, utilize research techniques, and consider any factors that might impact the outcomes (Jager et al., 2008; Polit & Beck, 2018). By adopting this approach, the reliability and trustworthiness of the findings will be increased.

Furthermore, more time and resources within the curriculum could be improved for effectively implementing SL (Yusof et al., 2020). Funding constraints and difficulties in interdisciplinary collaboration further hinder meaningful community engagement (Ejiwale, 2014). However, to maximize the impact of SL, the collaboration between programs and community organizations is crucial, fostering resource sharing and enhancing efficiency (World Health Organization, 2021). Additionally, measuring the sustained impact of SL in the long term presents challenges, as student outcomes often need to be tracked beyond their immediate participation (Tiven et al., 2018). To address this issue, it is imperative to develop reliable measures and establish collaborative partnerships with stakeholders while increasing research initiatives' funding (Tiven et al., 2018). Educators can better prepare students for real-world applications and accurately capture long-term outcomes by implementing improved pedagogical approaches and effective assessment methods.

CONCLUSION

The study highlight the mutually beneficial nature of SL, wherein students gain valuable experience such developing students' skills, problem-solving abilities, and career competencies and the community they serve reaps the benefit too. In addition, community engagement, collaborative learning, curriculum Integration, technology integration, and reflective practices are identified as meaningful ways to enhance the STEM curriculum, enabling students to learn through projects that address real-life problems related to sustainability concerns. However, the current study had limitations, including generalizations, data accessibility, methodological concerns, and impact assessments, that the next researcher must further note to allow the proper enactment of SL in higher learning institutions.

Author contributions: **NKI:** conceptualization, writing the original draft, visualization, and project administration; **SNDM:** data curation, methodology design, writing review and editing, and supervision. Both authors have sufficiently contributed to the study and agreed with the results and conclusions.

Funding: This study is funded by National University of Malaysia under the STEM and Minda RMK11 Grant.

Ethical statement: The authors stated that this study does not require an ethical committee approval as it is a subject of review of literature. Searching for data on the Scopus and WOS database is done via an official subscription account, namely Universitas Kebangsaan Malaysia.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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