Chapter 9

Innovation and Entrepreneurship Integration in STEM Education: eSTEM

Gizem Ozyazici

Syracuse University, United States of America

Chapter Highlights

The following points summarise the core rationale, key components, and key implementation challenges of integrating entrepreneurship into STEM education (E-STEM), highlighting its role in fostering innovation, real-world problem solving, and sustainable educational practices.

- Importance of STEM Education – Emphasises STEM's role in developing critical thinking and problem-solving skills essential for global competitiveness and societal progress.
- STEM and the Entrepreneurial Mindset (E-STEM) – Highlights how entrepreneurial thinking complements STEM by fostering creativity, adaptability, and innovation in real-world problem solving.
- Technology-Driven STEM Entrepreneurship – Examines the role of emerging technologies in enabling innovative STEM-based entrepreneurial solutions.
- Integrating Entrepreneurship into STEM Education – Focuses on project-based learning, design thinking, and teacher preparation as key strategies for effective E-STEM integration.
- Frameworks, Challenges, and Future Needs – Discusses theoretical models, key integration challenges, and the need for context-sensitive instructional models to support scalable E-STEM implementation.

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Introduction

In today's technology-driven world, it is significant to possess a unique set of skills such as critical thinking, argumentation, decision-making, and problem-solving (Deveci & Seikkula-Leino, 2023). These skills enable individuals to analyze complex situations, evaluate multiple perspectives, and develop effective solutions (Deveci & Seikkula-Leino, 2023; Ozyazici et al., 2025). While these skills are fundamental in STEM fields, where innovation often depends on the ability to approach challenges analytically and creatively, they are also essential in social and everyday life. For instance, navigating workplace dynamics, making personal financial decisions, or assessing information in the media, individuals use these skills in their daily life. These skills allow us to make informed choices and respond strategically to problems. Current literature further emphasizes that these competencies are not only vital in technical and scientific domains but also serve as foundational elements of entrepreneurial thinking (Mitchelmore & Rowley, 2010). Literature shows that entrepreneurship requires individuals to identify opportunities, manage uncertainty, and develop strategies for bringing innovative ideas to fruition all of which rely on these cognitive and problem-solving abilities (Deveci, & Seikkula-Leino, 2023). As a result, it can be concluded that there is a strong and mutually reinforcing link between STEM education and the entrepreneurial mindset, highlighting the need for educational programs that cultivate both technical expertise and adaptive, innovation-oriented thinking. Recently, some researchers have examined STEM students' entrepreneurial intentions (Shahin et al., 2021) as they can be seen as innovators and future scientists, developing creative products, securing patents, and driving progress in their fields. Moreover, with the growing recognition of the connection between entrepreneurship and STEM, universities and colleges have begun to integrate courses such as entrepreneurship, entrepreneurial thinking, and business fundamentals into their STEM curricula (Ewim, 2023). For instance, The NSF also supports STEM entrepreneurship through various initiatives, including the I-Corps program (Nnakwe, et al., 2018), Entrepreneurial Fellowships, and SBIR/STTR grants.

In today's world, entrepreneurship does not only mean running a business (Pozen, 2018), it is also about fostering innovation. In this context, the entrepreneurial mindset has often been emphasized in engineering literature, as engineering majors focus on designing, innovation, creation and building structures (Bosman, 2018). However, by considering the required skills for all STEM majors, including argumentation, data analysis, critical thinking, innovation, there is great potential for all STEM students—including those in chemistry, physics, and related disciplines—to transform their ideas into innovative solutions that address real-world challenges. Unlike the predominant focus on entrepreneurial intentions and mindset among business and engineering students, there is a gap in the literature suggesting that the perspectives, ideas, career developments of all STEM students should be examined (Ozyazici et al., 2025).

We see that entrepreneurship education literature focuses on business majors. Also, most research is limited to applying quantitative surveys, not validated for STEM students specifically and they do not provide qualitative insights into students' entrepreneurial mindset, experiences, challenges, and barriers. For instance, research shows that female STEM entrepreneurs face barriers such as masculine-dominated environments, limited access to funding, gender bias and stereotypes, work–life balance struggles, and the challenge of navigating social and cultural norms (Yusif et al., 2024). There is a need to discover more on this and provide more deeper understandings on STEM entrepreneurs and their experiences. Moreover, literature is also missing how to integrate structured EE programs into STEM curricula, in a way that all STEM students can benefit. While many colleges are integrating EE into their curricula, we still have limited knowledge about design, its effectiveness, long-term impacts, and potential career path changes. In addition, more research is needed on interventions and students' perspectives before and after these interventions. It is also important to consider instructional design approaches, such as the ADDIE model (Muruganantham, 2015) and to apply relevant frameworks to ensure that EE is integrated into STEM curricula at an appropriate and effective level.

Overall, STEM and entrepreneurship are closely connected, as both rely on innovation, problem solving, and applying knowledge to real-world challenges. Yet, entrepreneurship is often misunderstood and reduced to stereotypes such as wealth-seeking or college dropout success stories. In contrast, STEM entrepreneurship highlights how scientific and technological expertise can be used to meet diverse social needs and drive inclusive progress. Recognizing this link is essential for reimagining entrepreneurship as not only an economic activity but also a pathway for social impact and sustainable innovation. This chapter will explore the intersection of STEM and entrepreneurship, highlighting how entrepreneurial thinking can enrich scientific and technological innovation. It will examine key theoretical frameworks and methodological approaches that connect these domains, while also identifying the challenges that arise when integrating entrepreneurship into STEM education and practice. Finally, the chapter will discuss strategies and methods to address these challenges, offering insights into how educators, researchers, and practitioners can foster more sustainable and impactful connections between STEM and entrepreneurial pathways.

Importance of Science Education and STEM Education

Science education mainly and fundamentally aims to foster scientific literacy, a skill that is increasingly vital for navigating the complexities of contemporary society (Yacoubian, 2018). Scientific literacy not only enables individuals to make informed personal and civic decisions but also equips them to critically examine the accuracy of claims circulating in public discourse (Priest, 2013). In today's media-driven world, the prevalence of misinformation and pseudoscience has become a growing concern (Impey, 2024). The rapid spread of unverified information through digital platforms makes it easy for individuals to accept claims without question, particularly when media literacy and critical thinking skills are lacking. As a result, many people tend to believe what they encounter online or in popular culture without thoroughly evaluating or analyzing its validity, which is also related to lack of scientific literacy.

As we navigate global challenges like climate change, pandemics, and rapid technological advancements, individuals must be equipped to skills such as critical thinking, argumentation and make reasoned judgments (Erdogan et al., 2017). STEM education, particularly at the higher education level, plays a crucial role in cultivating these capabilities (Erdogan et al., 2017). It fosters essential 21st-century skills such as critical thinking, problem-solving, and evidence-based argumentation (Lamb et al., 2017), skills that are emphasized in STEM.

Lastly, STEM education is a driver of economic growth and innovation. A well-prepared STEM workforce fuels technological advancement, scientific discovery, and entrepreneurship. However, despite its importance, STEM education faces significant challenges, high dropout rates remain a persistent concern, with fewer than 40% of students who begin college intending to major in STEM completing their degrees in these fields (Eagan et al., 2014; Sithole, et al., 2017). The reason for this could be lack of instructional strategies such as mentorship, culturally responsive teaching, and the creation of supportive learning environments. Ultimately, strengthening STEM education in higher education is not just about producing more scientists and engineers, it is about empowering all students with the tools to understand the world around them, contribute meaningfully to society, as well as economy.

Goals of STEM Education

The goals of STEM education extend beyond teaching science, technology, engineering, and mathematics content. A STEM-literate student should be able to think critically, ask meaningful questions, and apply knowledge to solve real-world problems (Ah-Namad & Osman, 2018). STEM education also emphasizes developing problem-solving skills, curiosity, creativity, teamwork, and communication, enabling students to collaborate effectively and adapt to emerging industries. In engineering contexts, students are encouraged to design solutions to authentic challenges. Teachers play a central role in this process by facilitating hands-on learning experiences that make lessons relevant and engaging. Additionally, STEM education fosters resilience, adaptability, ethical reasoning, and digital literacy. Collectively, these competencies prepare students not only for future careers but also for active and responsible citizenship

STEM education, especially in the twenty-first century, aims to prepare students not only with technical knowledge but also with the skills, attitudes, and competencies necessary to thrive in an increasingly complex, interconnected, and innovation-driven world. However, as Lin et al. (2022) noted, there is still no universal consensus among educators and researchers on the specific goals of STEM education, which makes its promotion and implementation challenging. A survey of 645 Taiwanese secondary STEM teachers showed broad support for 17 competencies such as creativity, critical thinking, and problem-solving, though entrepreneurial skills were less emphasized (Lin et al., 2022). The authors argue entrepreneurship should be prioritized in tertiary STEM education to prepare students for diverse careers. They also found that teachers' willingness to adopt integrative STEM approaches increases with institutional support. Similarly, Jannini et al. (2024) reported that supportive cultural and institutional environments foster mastery orientations in undergraduates, while anxiety hinders engagement. Together, these findings highlight the need for STEM goals to address both cognitive and affective domains, building perseverance, adaptability, and resilience alongside achievement. These findings show the need for STEM education goals to address both cognitive and affective domains, fostering perseverance, adaptability, and resilience alongside academic achievement.

Another element that we emphasize in terms of STEM education goals is building critical media literacy. Students today are surrounded by media that strongly shapes how people see science and technology. Without the ability to question sources and check facts, it is easy to believe misinformation. For instance, critical media literacy helps students analyze information carefully, spot biases, and recognize when claims are not supported by evidence (Kellner & Share, 2019). By combining STEM education with media literacy, students learn both the technical skills and the critical awareness needed to understand the world around them. This approach ensures that they are prepared not only to succeed in STEM careers but also to make thoughtful decisions in a society filled with complex information.

The link between STEM and Entrepreneurial Mindset (E-STEM)

The entrepreneurial mindset connects very closely with many of the main goals of STEM education. Having an entrepreneurial mindset means being able to see opportunities, use available resources wisely, and create something that has value in different areas of life (Olawale et al., 2020). It is not only about starting a business but also about thinking creatively, solving problems, and bringing new ideas to real situation (Kuschell et al., 2020). Skills such as creativity, problem-solving, and innovation are also at the heart of STEM education. In addition, developing an entrepreneurial mindset helps students build important qualities such as adaptability, resilience, and collaboration, which prepare them for challenges in both their careers and daily lives (Adeoye et al., 2024). One way to build this mindset is through experiential and problem-based learning, where students learn by doing rather than only by reading or listening. For example, Olawale et al. (2020) describe an engineering design lab model where students worked on authentic, real-world problems. In this setting, students not only applied their STEM knowledge but also practiced working as a team, thinking in creative ways, and reflecting on their learning with the help of mentors. This kind of approach shows how STEM education and entrepreneurship can come together, giving students experiences that are practical, meaningful, and closely connected to the real world.

Literature shows that entrepreneurship and STEM are interconnected, with STEM disciplines driving innovation and problem-solving (Deveci & Seikkula-Leino, 2023). However, it is important to first define entrepreneurship and entrepreneurial mindset. In literature, entrepreneurship is generally associated with individuals who possess distinct abilities, particularly those that drive innovation (Gartner, 1990). It is a dynamic process, and it is characterized by creativity, developing and implementing new ideas and solutions (Kuratko et al., 2021). Furthermore, an entrepreneurial mindset enables individuals to identify opportunities amid uncertainty and complexity, transforming challenges into possibilities (Kuratko, 2020). Developing an entrepreneurial mindset within STEM education can empower students to translate innovative ideas into viable solutions, address complex challenges, and identify market opportunities (Deveci & Seikkula-Leino, 2023; Galloway et al., 2006), which our society needs. Entrepreneurship provides opportunities for STEM graduates to apply their technical skills and knowledge in innovative and dynamic ways (Zahra et al., 2006). The term entrepreneurial mindset is often associated with engineering education. However, in reality, all STEM students have the potential to turn their ideas into practical solutions (Nguyen et al., 2019), especially when we look at the founders of STEM-related companies. STEM graduates often perceive fewer career options than those in other fields (Jelks & Crain, 2020), which may increase their willingness to explore alternative careers (Gilmartin et al., 2019) and STEM entrepreneurship could provide new career opportunities that extend beyond the conventional roles associated with STEM, allowing graduates to apply their skills in innovative ways. STEM students frequently excel in leadership, innovation, and problem-solving (Li & Li, 2023), enabling them to address complex challenges entrepreneurially. Research shows that nonbusiness students, particularly in science and engineering, can successfully transform ideas into viable ventures by developing entrepreneurial skills (Åstebro et al., 2012). Moreover, an entrepreneurial mindset could enable individuals to identify opportunities (Hölzner & Halberstadt, 2022), this aligns with STEM goals, requiring critical thinking and problem-solving (Ewim, 2023). Entrepreneurship is not limited to business students but is accessible to anyone with interest (Ewim, 2023). Studies highlight its strong link to STEM, showing how fostering this mindset bridges the gap between innovation and market application while developing key skills like opportunity recognition and strategic planning (Deveci & Seikkula-Leino, 2023; Kuschel et al., 2020).

Overall, the overlap between entrepreneurial mindset, creativity, argumentation, evaluation skills, and problem-solving reflects a shared objective of STEM education: to equip learners with the capacity to generate novel ideas, address complex problems, and contribute meaningfully to society. In a rapidly evolving global economy, these interconnected competencies are not supplementary but essential for ensuring that STEM graduates can lead innovation across sectors. This integration of entrepreneurship into STEM has increasingly been recognized as E-STEM, highlighting how entrepreneurial practices can enhance traditional STEM competencies.

Technology in STEM Entrepreneurship

Technology-driven entrepreneurship can show how STEM knowledge can be transformed into practical innovations that address real needs. Examples such as smart swim goggles, LED-equipped bike helmets, 3D-printed prosthetics, drone delivery of medical supplies, and sustainable textiles highlight how technology fosters both economic growth and social good. By linking scientific knowledge with entrepreneurial thinking, STEM professionals learn to spot unmet needs, apply solutions, and build scalable ventures that generate lasting impact.

Integrating Entrepreneurial Education (EE) into STEM

Universities play a pivotal role in shaping entrepreneurial mindsets. Studies have shown that EE fosters students' ability to act on their ideas and expand their career prospects (Klofsten et al., 2020; Shane, 2008). Institutions that promote EE contribute to the creation of entrepreneurial ecosystems, cultivating cultures of innovation that support future economic growth (Guerro et al., 2016; João & Silva, 2020). In the context of STEM education, incorporating EE aligns with its foundation because it could enhance students' capacity for innovative thinking and real-world problem solving. While engineering education has made notable progress in integrating EE through experiential learning and co-curricular programs (Lei et al., 2023), gaps remain in its implementation across other STEM disciplines such as biology and chemistry.

Recent literature shows EE research is becoming more interdisciplinary, yet contributions from science and technology disciplines are still limited (Tiberius & Weyland, 2023). Addressing these gaps requires not only quantitative assessments of EE outcomes but also qualitative exploration of students' experiences and perceptions (Ceyhan & Tillotson, 2020; Zhao & Zhang, 2021). Lastly, the effectiveness of EE varies depending on factors such as students' academic majors, gender, nationality, and level of education. For example, while French and Polish students reported positive outcomes after EE courses, male German students showed less favorable results, illustrating the need for context-specific pedagogical strategies (Packham et al., 2010). These findings are consistent with the Theory of Planned Behavior (Ajzen, 1991), which posits that attitudes influenced by education can shape intentions and ultimately behavior. Although research on integrating EE into STEM education is growing, the number of studies remains limited (Yu, Zheng, & He, 2025). It can be concluded that entrepreneurial and STEM education share a close connection, as they are mutually beneficial and reinforcing.

Bringing EE into STEM helps create a more complete learning experience, where students develop creativity, problem-solving, and practical skills while also preparing for future careers and industries.

Yu et al. (2025) analyzed 31 studies on entrepreneurial education in STEM published between 2012 and 2023 across thirteen countries. The United States contributed the most with 36% (11 studies), followed by Turkey with 19% (6 studies). Smaller contributions came from the United Kingdom, Malaysia, and Italy. These results reflect the field's international scope as well as its concentration in developed countries. Methodologically, qualitative designs were most prevalent (58.1%), followed by mixed methods (32.3%), and then quantitative studies (29.0%). Case studies were the most common, and interviews, used in six studies, were valuable for capturing students' perspectives on how entrepreneurial education shapes STEM learning. Participants ranged from primary school students to doctoral candidates, with the largest group being undergraduates (13 studies). Teachers were well represented, especially in-service teachers (16 studies). However, there was limited attention to pre-service teachers and STEM undergraduates, who are central to building future STEM capacity. More research with these populations is needed to guide classroom integration and workforce preparation. Overall, future studies should address the specific needs of STEM students by combining qualitative and quantitative approaches and exploring instructional design strategies for incorporating entrepreneurial education into higher education curricula.

Integrating entrepreneurship into STEM education, often referred to as E-STEM, presents both opportunities and challenges, particularly within higher education. STEM intervention programs, STEM-related academic departments, and business schools each have the potential to incorporate entrepreneurial elements into their curricula. Doing so not only supports students' career trajectories but also equips them with essential entrepreneurial skills, which are increasingly necessary in today's innovation-driven economy. Embedding entrepreneurship in STEM programs can help students move beyond technical expertise to become innovators capable of translating ideas into real-world solutions. The importance of such integration is reflected in initiatives like the U.S. National Science Foundation's Entrepreneurial Fellowships for engineers and scientists, launched in 2022 through a $20 million investment in partnership with Activate.org. This program supports fellows from diverse backgrounds to transform research breakthroughs into products and services with broad societal impact. However, despite these advancements, integration remains uneven, often hindered by disciplinary silos, lack of cross-department collaboration, and limited institutional resources. Globally, there is growing momentum in E-STEM, but efforts vary widely. India's tinkering labs in over 10,000 K-12 schools are fostering early STEM entrepreneurship, Germany is expanding youth entrepreneurship labs, and Europe is funding hybrid STEM-business ventures. In the United Kingdom, commercialization of scientific breakthroughs is becoming a policy priority. Yet, these examples also highlight disparities in access, resources, and scalability, underscoring the need for sustained investment, institutional alignment, and cross-sector partnerships to fully realize the potential of E-STEM worldwide.

Literature highlights the importance of STEM intervention programs for broadening participation and supporting student success in science and engineering (Ceyhan & Tillotson, 2020; Rodriquez et al., 2020). Embedding entrepreneurship education (EE) within these programs can further enhance students' career development by expanding their aspirations beyond traditional STEM pathways (Deveci & Seikkula-Leino, 2023). This integration is not about reinforcing the popular narrative of college dropouts becoming wealthy entrepreneurs; rather, it emphasizes preparing diverse STEM students to innovate and pursue meaningful careers that respond to both market demands and societal needs. Evidence from Souitaris et al. (2007) demonstrates that entrepreneurship programs can significantly increase the entrepreneurial intentions of science and engineering students, underscoring the value of educational interventions in shaping career decisions. Still, effective strategies for embedding EE into STEM programs remain underdeveloped (Deveci & Seikkula-Leino, 2023). Integrating EE across disciplines is essential for equipping students with the mindset and tools to address real-world problems (Kuschel et al., 2020; Nguyen et al., 2019). Yet, most existing studies focus primarily on business and engineering majors (Barba-Sánchez & Atienza-Sahuquillo, 2018; Kurata et al., 2023), overlooking the broader STEM population.

Recent work shows that universities are beginning to integrate EE into STEM curricula, though often only partially or in limited contexts. Research demonstrates that entrepreneurial practices can be incorporated through interdisciplinary approaches that connect knowledge across domains (Eltanahy et al., 2020). However, implementing E-STEM also presents significant challenges, including limited teacher training, heavy curricular demands, and difficulty in assessing entrepreneurial practices effectively.

Challenges of Integration E-STEM

STEM leaders have identified barriers such as limited teacher training in entrepreneurial learning, students' readiness to think beyond classroom tasks, and teachers' heavy curricular workloads. (Eltanahy et al., 2020). Additional challenges include assessing entrepreneurial practices effectively, sustaining student motivation, particularly in contexts where learners may lack incentives, and ensuring that outcomes extend beyond models to include innovative ideas, projects, or social services. These findings show the need for systemic support and interdisciplinary approaches to make E-STEM sustainable and impactful (Eltanahy et al., 2020).

Gender Issues

Women STEM entrepreneurs are crucial for driving innovation, fostering inclusivity, and addressing pressing societal challenges (George, 2024). Their unique perspectives often lead to more diverse, equitable, and creative solutions, enriching the innovation ecosystem. Women in entrepreneurship are more likely to address unmet needs, particularly those affecting women and underrepresented groups (Irwin, 2025) while challenging existing norms and fostering more dynamic, inclusive innovation. Despite these contributions, a significant gender gap persists in E-STEM, limiting the potential impact of women entrepreneurs. Closing this gap is not only a matter of equity but also of economic necessity. Research shows that increasing women's participation in entrepreneurship could significantly boost global development (Sajjad et al., 2020). However, systemic barriers hinder women's full participation in STEM entrepreneurship. Without targeted support, such as mentorship programs, equitable funding mechanisms, and inclusive curricula, women entrepreneurs remain underrepresented.

Their absence shows inequity, also reduces the diversity of perspectives necessary for addressing complex global challenges. Therefore, integrating gender equity into E-STEM initiatives is therefore essential for building a more innovative, and economically vibrant future. Moreover, challenges extend more broadly to include students from racially minoritized groups, low-income backgrounds, and first-generation college families. These students often face compounded barriers in accessing entrepreneurial ecosystems, mentorship opportunities, and early-stage funding. Without intentional design and targeted support, E-STEM risks reinforcing existing disparities rather than alleviating them (Ong et al., 2018).

Curricular Overload and Rigid Structures

STEM curricula are often already packed with technical and disciplinary requirements, leaving little flexibility to integrate entrepreneurship content. Faculty may resist adding entrepreneurship modules out of concern that they will displace essential disciplinary knowledge or extend students' already heavy workload (Borrego & Henderson, 2014). This structural rigidity creates one of the first barriers to embedding E-STEM within higher education.

Faculty Expertise and Training

Even when institutions make space for entrepreneurship content, many STEM instructors lack the formal training or confidence to teach entrepreneurial principles. As a result, programs often depend on external partners such as business schools or industry mentors, which can lead to inconsistency and uneven program quality (Baik et al., 2019). Developing faculty capacity is therefore critical for sustaining high-quality E-STEM initiatives.

Assessment and Measurement

Another significant challenge involves the evaluation of entrepreneurial education. Constructs such as entrepreneurial mindset, creativity, and innovation capacity are difficult to measure with conventional STEM assessment tools. Without valid and reliable instruments, it becomes challenging for institutions to demonstrate outcomes, secure funding, or justify the curricular space dedicated to E-STEM (Ozyazici et al., 2025).

Cultural Perceptions of Entrepreneurship

Within some academic contexts, entrepreneurship is perceived as less rigorous or even incompatible with the ideals of "pure" STEM research. Such cultural perceptions can reduce faculty buy-in and discourage students who fear that pursuing entrepreneurship may undermine their credibility as scientists or engineers (Feldman & Kenney, 2004). Changing these perceptions requires a cultural shift in how higher education values entrepreneurial pathways.

Theoretical Frameworks in STEM and Entrepreneurial Education

The development of entrepreneurial thinking among STEM students is often examined through the Theory of Planned Behavior (TPB) (Ajzen, 1991; Montes et al., 2023) and Social Cognitive Career Theory (SCCT) (Duong & St-Jean, 2024). TPB emphasizes the formation of entrepreneurial intentions by considering individuals' attitudes toward entrepreneurship, subjective norms, and perceived behavioral control. In contrast, SCCT focuses more broadly on career development pathways, highlighting how self-efficacy beliefs, outcome expectations, and environmental supports or barriers influence students' decisions and persistence in entrepreneurial careers (Tran & Von Korflesch, 2016). Despite their contributions, the literature shows limited use of SCCT in exploring the entrepreneurial mindset of STEM learners, creating opportunities for new research. Recent scholarship suggests that one theory alone may not fully explain the complex process through which STEM students develop entrepreneurial pathways. For example, Ozyazici et al. (2025) applied both SCCT and TPB in examining entrepreneurial career development, showing how these frameworks complement each other by addressing both intention formation and broader contextual influences. Integrating these perspectives provides a more holistic understanding of how STEM students' values, self-beliefs, and perceived opportunities shape their entrepreneurial goals. In this study, the authors also developed the STEM Entrepreneurship Career Development Measure (SECDM), a theoretically grounded instrument designed to capture the unique experiences and aspirations of STEM students in entrepreneurial contexts (Ozyazici et al., 2025).

The creation of SECDM has important implications for both research and practice. First, it fills a critical gap in measurement by offering a tool that accounts for the motivational, cognitive, and contextual factors emphasized in SCCT and TPB. Second, it provides a foundation for evaluating the effectiveness of entrepreneurship-focused STEM intervention programs. With valid measures, educators and program designers can more accurately assess changes in students' entrepreneurial intentions, self-efficacy, and outcome expectations over time. This, in turn, allows for the design of targeted instructional strategies and interventions that not only build entrepreneurial competencies but also address barriers faced by underrepresented groups. Furthermore, another set of measures, such as the Entrepreneurial Intention Questionnaire (Liñán & Chen, 2009), the Entrepreneurial Self-Efficacy Scale (Zhao et al., 2005), and entrepreneurial mindset scales (Adebusuyi et al., 2022; Hirschi, 2014), are also very important in the entrepreneurship literature, and they need to be tested with STEM student populations to evaluate their relevance and validity in this context. Doing so would expand the methodological base of STEM entrepreneurship research and provide stronger tools for assessing intervention programs, ensuring that instructional strategies effectively foster entrepreneurial intentions, self-efficacy, and equitable opportunities for diverse learners.

Another framework to add or follow could be the ADDIE framework

(Analysis, Design, Development, Implementation, and Evaluation), that provides a systematic model for integrating entrepreneurship education into STEM curricula (Muruganantham, 2015). In the Analysis phase, educators can identify students' existing entrepreneurial knowledge, intentions, and contextual barriers through surveys, interviews, or diagnostic assessments. The Design and Development phases allow for the creation of targeted interventions—such as project-based learning, mentorship opportunities, or case studies—that explicitly connect STEM knowledge with entrepreneurial skills. During Implementation, these strategies can be embedded into STEM courses, intervention programs, or co-curricular activities, ensuring that entrepreneurship is taught not as an add-on but as part of disciplinary learning. Finally, the Evaluation phase ensures continuous improvement by assessing changes in students' entrepreneurial self-efficacy, intentions, and outcomes, while also highlighting areas for refinement. Applying ADDIE in this way helps bridge theory and practice, ensuring that interventions are both evidence-based and responsive to the diverse needs of STEM learners. Moreover, while quantitative studies guided by the Theory of Planned Behavior (Ajzen, 1991) dominate the field, qualitative work is necessary to capture students' lived experiences (Mensah et al., 2021; Montes et al., 2023). Listening to students' voices is vital for designing interventions that cultivate entrepreneurial mindsets, creativity, and innovation, while also supporting the career aspirations of the future STEM workforce.

Need for Specific Models

Entrepreneurship education within STEM programs requires carefully designed instructional models that move beyond business-oriented frameworks to address the specific needs of STEM students. Effective strategies often include online learning modules that introduce entrepreneurship concepts, opportunities to interact with guest speakers and industry professionals, and structured peer engagement through collaborative projects or discussion forums. These approaches help students connect theoretical content to practical, real-world applications, thereby fostering entrepreneurial thinking within STEM contexts.

Embedding entrepreneurship education into existing seminar courses represents another effective strategy, as it ensures accessibility and contextual relevance. Rather than positioning entrepreneurship as an add-on, integrating it into existing coursework provides structured opportunities for reflection and engagement. This approach aligns with learner-centered instructional design principles that emphasize relevance, authenticity, and active learning (Merrill, 2002). Furthermore, adopting a systems-thinking perspective acknowledges that entrepreneurship education is shaped not only by the classroom environment but also by institutional policies, career services, and external networks. Equity and access must be considered central design features. Research shows that female-friendly curricula and sensitivity to women's perspectives can help address persistent gender gaps in STEM (Cheng & Lo, 2022). At the same time, programs must intentionally design for the inclusion of first-generation college students, students from low-income backgrounds, and racially minoritized groups to ensure that entrepreneurship education opportunities are not disproportionately available to those with more resources or privilege. Such inclusive approaches require continuous evaluation to avoid reinforcing inequities that already exist in STEM higher education.

Finally, scholars emphasize that entrepreneurship education should be democratized and accessible across disciplines, not limited to business students. Entrepreneurial skills empower individuals to contribute socially and economically as proactive citizens, making entrepreneurship education a critical component of preparing students for participation in democratic societies (Ewim, 2023; Ribeiro et al., 2023).

Additionally, scalability and sustainability remain persistent concerns for entrepreneurship education in STEM. While guest speakers, industry partnerships, and mentoring programs are highly valued by students and shown to strengthen career readiness, such strategies often require significant financial resources, administrative coordination, and faculty time (Fayolle & Gailly, 2015). Without institutional commitment—such as funding for ongoing programming, recognition of faculty workload, and integration into long-term curricular planning—these initiatives risk being short-lived pilot efforts rather than durable transformations. Moreover, sustainable models must balance quality with reach; expanding entrepreneurship opportunities to a wider pool of students cannot come at the expense of program depth or individualized support. Embedding entrepreneurship education within institutional priorities, including diversity and workforce development initiatives, offers one pathway for ensuring both longevity and equitable access.

Discussion

Recognizing the role of STEM entrepreneurship is crucial for changing how society perceives entrepreneurs. Too often, entrepreneurs are stereotyped as college dropouts chasing profit or as individuals focused only on building wealth. This narrow view overlooks the broader contributions of entrepreneurship, particularly when grounded in STEM. STEM entrepreneurs bring together scientific knowledge, technological skills, and an innovative mindset to address complex and diverse societal needs. Rather than fitting the stereotype, they create solutions that improve healthcare, education, sustainability, and equity. By highlighting the social and community-focused impact of STEM entrepreneurship, higher education and policy can help shift public perception: from seeing entrepreneurs as profit-driven to understanding them as problem-solvers, innovators, and leaders who respond to the needs of diverse populations. This reframing is essential to inspire the next generation of students to view entrepreneurship not only as a career option but as a pathway to social change and inclusive progress.

Overall, the literature consistently shows that STEM and entrepreneurship are deeply interconnected, particularly when considering the skills demanded in today's innovation-driven economy. Integrating entrepreneurship into STEM curricula not only prepares students for emerging career paths but also fosters critical competencies such as creativity, problem-solving, risk-taking, and adaptability (Adebusuyi et al., 2022; Yu et al., 2025). Many universities have already begun embedding entrepreneurial education into engineering, science, and technology programs, often through innovation hubs, maker spaces, or incubator programs that allow students to prototype and pitch their ideas (Hirschi et al., 2014). For instance, institutions such as MIT and Stanford have long blended engineering design with entrepreneurial training, while Europe's EIT InnoEnergy program explicitly links sustainable energy innovations with entrepreneurship to address global climate challenges (Yu et al., 2025). Importantly, this integration should not be confined to higher education alone. Preparing future teachers to incorporate entrepreneurial thinking into their practice can bring these skills to younger students, laying a foundation for innovation at earlier ages. Small-scale interventions, such as having middle school science students design low-cost water filtration systems, build simple apps, or experiment with sustainable materials, illustrate how entrepreneurial mindsets can be developed through authentic STEM problem-solving (Liñán & Chen, 2009). Globally, programs such as India's Atal Tinkering Labs or Singapore's national emphasis on innovation within STEM curricula demonstrate that entrepreneurial elements in STEM education empower students to become solution-seekers for real-world problems (World Bank, 2020). Thus, fostering entrepreneurial skills within STEM classrooms, whether at the university level or in middle schools, ensures that the next generation is prepared to translate scientific knowledge into scalable, socially impactful solutions, driving both economic growth and societal resilience.

Another important discussion point concerns how to design appropriate-level interventions or lesson plans that effectively integrate entrepreneurship into STEM learning. While the literature demonstrates the value of E-STEM integration, there is still a lack of systematic frameworks for instructional design that guide teachers in tailoring entrepreneurial content to different age groups and educational contexts (Yu et al., 2025). Designing interventions that are developmentally appropriate is essential: for instance, modules for middle school science may emphasize creativity, teamwork, and problem identification, whereas higher education interventions can include market analysis, prototyping, and venture creation (Adebusuyi et al., 2022). Some research has already experimented with such integrations. For example, Rauch and Hulsink (2015) developed entrepreneurship modules in engineering curricula that improved students' entrepreneurial self-efficacy and opportunity recognition. However, these studies remain relatively isolated, and more models are needed to provide teachers—both at K–12 and higher education levels—with clear strategies for weaving entrepreneurial elements into STEM lessons. Drawing from established instructional design approaches, such as ADDIE or Merrill's First Principles, could support the structured development of E-STEM curricula that balance content knowledge with innovation skills. Expanding this line of research would not only strengthen the evidence base but also equip educators with practical frameworks to embed entrepreneurial thinking meaningfully into science and engineering classrooms.

Conclusion

Entrepreneurship in STEM (E-STEM) is a promising but still developing area in education and research. Evidence shows that STEM and entrepreneurship share important skills such as critical thinking, problem solving, and the ability to apply knowledge in real-world settings. Yet, the current approaches to integrating entrepreneurship into STEM remain limited and often focus only on engineering students. To be effective, integration should consider students' majors, prior knowledge, academic level, and career intentions. Bringing entrepreneurship into STEM education does more than expand technical knowledge. It helps students become innovators who can turn ideas into solutions that support both economic growth and social progress. At the same time, several challenges must be addressed. Reliable assessment tools are lacking, which makes it difficult to measure outcomes and justify investment. Cultural views in some institutions still treat entrepreneurship as less rigorous than traditional STEM work, limiting support from faculty and students. Equity concerns also remain, especially for students from racially minoritized, first-generation, or low-income backgrounds who face barriers to resources and mentorship. Without targeted support, E-STEM could unintentionally reinforce these inequalities. Even so, the potential impact of E-STEM is clear. Embedding entrepreneurial pathways into STEM programs can open opportunities, broaden participation, and prepare students to contribute as active citizens in an innovation-driven world. Future progress depends on developing strong measurement tools, creating inclusive learning environments, and building stronger links between STEM fields and business education. Institutions also need to recognize and value entrepreneurial achievements alongside traditional academic success. E-STEM should not be seen as an optional addition but as a necessary part of preparing the next generation of scientists, engineers, and innovators. With intentional design and inclusive practices, higher education can foster entrepreneurial mindsets that enable students to lead change, address diverse needs, and shape both technological and social futures.

Recommendations

Future research and practice in STEM entrepreneurship education should prioritize validating existing entrepreneurship surveys with STEM student populations, as measures widely used in the literature may not fully capture their unique experiences. Combining theoretical frameworks such as TPB and SCCT can provide a more comprehensive understanding (Ozyazici et al., 2025) of intention formation and contextual influences, while methodological rigor should be strengthened by employing reliability indices like McDonald’s omega, which offers a more robust estimate of internal consistency than Cronbach’s alpha (Dunn et al., 2014). At the same time, educators and policymakers must work to change societal stereotypes that frame entrepreneurs as merely profit-driven, highlighting instead how STEM entrepreneurship can empower students across all disciplines, not just engineering, design innovative solutions that address diverse and pressing real-world problems. Such efforts can expand participation, foster inclusivity, and position STEM entrepreneurship as a pathway for both social impact and economic progress. Future research could talk more on qualitative findings on STEM entrepreneurship, design specific interventions for targeted groups, there is a lack of information about students, or workers personal experiences about STEM entrepreneurship and/or STEM entrepreneurship classes.

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About the Author

Gizem Özyazıcı is a PhD candidate in the Department of Science Teaching at Syracuse University. Her expertise spans both quantitative and qualitative research methods. Her research focuses on STEM education, STEM and entrepreneurship, teacher education, and assessment.

gozyazic@syr.edu
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