*Environment and Social Psychology (2025) Volume 10 Issue 12*
doi: 10.59429/esp.v10i12.3299

ISSN: 2424-8975 (O)
2424-7979 (P)

**RESEARCH ARTICLE**

# Exploring Innovative Mindsets of Higher Education Learners for STEM Skills through Social Learning Perspectives

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## ABSTRACT

Innovative mindset helps students embrace interdisciplinary approaches, enabling them to integrate knowledge from various domains and collaborate effectively with others. In doing so, they contribute not only to technological and scientific progress but also to societal growth by addressing pressing social concerns. This paper explored how classrooms fostered innovative mindsets among college students through social learning processes. This exploratory study gathered narratives from 16 science, technology, engineering, and mathematics (STEM) students in Biliran Province about their experiences that cultivate their innovative mindset in academic settings. Participants were purposively sampled, and data were analyzed using reflexive thematic analysis. The findings indicated that innovative mindset in STEM students is viewed as a triad of flexibility, creativity, and knowledge. Innovation was not limited to generating new ideas but also involved adapting to changing circumstances and applying learned knowledge to solve problems. Teachers who create a collaborative and inquiry-driven classroom environment facilitated students in approaching challenges from multiple perspectives and experimenting with solutions. The ability of teachers to simplify and break down problems into manageable parts served as a form of cognitive modeling, which encouraged students to adopt similar methods when solving their own issues. This strategy not only enhanced understanding but also built confidence in managing challenges innovatively. Cultivating an innovative mindset requires a combination of adaptive teaching strategies, effective integration of technology, and a supportive learning environment. These elements help students develop the critical thinking and problem-solving skills necessary for success in STEM fields and beyond.

***Keywords:*** creativity; higher education; innovative mindset; social learning; STEM

## 1. Introduction

The evolving landscape of education responds to the dynamic demands of society and technological progress, with Science, Technology, Engineering, and Mathematics (STEM) education emerging as a pivotal force in this transformation [1]. As global challenges become increasingly complex, the relevance of STEM fields grows, driven by rapid technological advancements [2]. Its role in strengthening economic prosperity and global competitiveness is well-established; however, a persistent issue remains low enrollment and widespread disinterest in STEM fields, even after significant reforms and investments [3-5]. This signals the need for a more understanding of the barriers and motivators influencing STEM engagement.

**ARTICLE INFO**
Received: 10 December 2024 | Accepted: 15 December 2025 | Available online: 26 December 2025

**CITATION**
AMPONG TA. Exploring Innovative Mindsets of Higher Education Learners for STEM Skills through Social Learning Perspectives. *Environment and Social Psychology* 2025; 10(12): 3299 doi:10.59429/esp.v10i12.3299

STEM education equips individuals with essential skills such as analytical thinking, creativity, and problem-solving, which are critical not only for personal career success but also for societal progress [6-7]. It prepares learners to address pressing global challenges, including climate change, healthcare, and technological innovation. By fostering a culture of critical thinking and innovation, STEM education has far-reaching implications for both individual growth and societal development [8,9]. The development of a STEM-skilled workforce is crucial to devising solutions for global issues, ensuring that STEM education contributes significantly to societal well-being and advancement.

An innovative mindset is crucial for success in STEM fields, as it drives problem-solving and cultivates creativity in addressing challenges. An innovative mindset involves the ability to think critically, challenge existing paradigms, and find new solutions to problems, which are essential skills for STEM professionals who must navigate a rapidly evolving technological landscape [10]. In STEM education, cultivating an innovative mindset enables students to approach learning with curiosity and resilience. According to Dweck [11], a mindset comprises attitudes and beliefs that shape how individuals respond to challenges. Students with an innovative mindset are more likely to embrace failure as a learning opportunity and persist through obstacles, which is critical in fields that require constant experimentation and adaptation [12]. Traits such as creativity, adaptability, and critical thinking are associated with an innovative mindset [13]. These qualities are not only useful for producing novel ideas but also for applying them in practical, real-world contexts. STEM students with an innovative mindset are more capable of translating their theoretical knowledge into groundbreaking solutions that address issues such as climate change, healthcare, and technology [14].

For effective learning to happen, there is a need for a positive classroom environment. Social learning theory explains how individuals acquire knowledge and behavior by observing models, such as peers, mentors, or community leaders [15,16]. Similarly, developing an innovative mindset in STEM involves exposing students to models of creative problem-solving, critical thinking, and adaptive strategies in real-world contexts. Interaction is central to cognitive, social, and cultural development within constructivist and constructionist paradigms, emphasizing that learning is most effective when it involves active collaboration and tangible outcomes [17,18]. For example, makerspaces exemplify this by developing environments where learners design, create, and share projects, using diverse resources while engaging in meaningful dialogue and collaboration [19,20]. Dialogue in educational contexts is dynamic, involving diverse perspectives that enhance understanding and adaptability through mutual exchange [21,22]. This interaction enables inter-thinking, where shared knowledge and skills combine to solve problems creatively and effectively, often surpassing individual capabilities [23].

## 2. Literature review

Over the years, STEM education has evolved into a comprehensive and interdisciplinary approach that transcends traditional subject boundaries. It is designed to integrate science, technology, engineering, and mathematics into a cohesive learning experience that emphasizes real-world applications [24,25]. This educational framework is rooted in the understanding that these disciplines are interwoven into the fabric of everyday life, thus demanding essential skills like critical thinking and problem-solving. The integrated approach not only enhances academic engagement but also equips students to address contemporary challenges effectively.

In the modern, technology-driven world, STEM education has emerged as a necessity rather than a mere academic requirement. As societal advancements increasingly rely on technology, students must develop a robust set of skills to navigate complex global challenges [26]. STEM education prepares learners to adapt and innovate, instilling competencies that are vital in today’s fast-paced environment. The shift from traditional education to a more practical and interdisciplinary model is pivotal in equipping students to apply theoretical knowledge to real-life problems. Higher education institutions have been at the forefront of encouraging innovation competence among students, which has become essential for professional success. Recognizing the need for 21st century skills, many universities are embracing strategies that emphasize creativity and adaptability [27]. These strategies often include experiential learning, collaborative projects, and problem-based approaches that challenge students to think critically and apply their skills in new contexts [28]. Such initiatives reflect a commitment to preparing graduates for a world where innovation is a key driver of progress.

The successful implementation of STEM education hinges on strategic curriculum design, effective teaching methods, and the integration of advanced technology [29]. To engage students meaningfully, educators are employing project-based learning, hands-on experiences, and technology-driven instruction. These methods not only make STEM concepts more accessible but also enable students to connect theoretical knowledge with practical applications. The emphasis on experiential learning ensures that students are better prepared to face real-world challenges with innovative solutions. Further, real-world applications embedded within STEM curricula are critical for student engagement and comprehension [30]. When students see the practical relevance of their education, they are more likely to develop a genuine interest in STEM fields and be equipped to address pressing societal issues [31].

Learners' mindsets have gained increasing attention in educational contexts because they play a critical role in understanding variations in learner performance and predicting long-term academic outcomes [32,33]. Mindsets, as beliefs about one's intelligence and abilities, influence behavior and performance, especially in subjects like mathematics, which are typically viewed as rigid, formulaic, and abstract [34,35].

Social learning processes can encourage individuals to develop their innovative mindset. Social Learning Theory (SLT), rooted in behaviorism, is a psychological framework proposed by Albert Bandura in 1952. It explores how the interaction between the learning environment, cognition, and behavior influences human learning [36]. SLT emphasizes the role of the environment and individual behavioral factors in shaping learning outcomes [37]. The theory suggests that effective learning can occur through a supportive environment, continuous observation, and self-directed learning [38]. In entrepreneurship, Zapkau et al. [38] showed that exposure to entrepreneurial role models, particularly parents, significantly influences individuals' attitudes towards self-employment and their entrepreneurial intentions. Türk, Zapkau and Schwens [39] discovered that prior exposure to entrepreneurship, either through role models or direct experience, impacts the development of entrepreneurial passion, emphasizing the role of learning orientation in entrepreneurial growth. Yang et al. [40] emphasized the applicability of SLT for farmer entrepreneurs, noting that they often start their ventures by imitating others, with environmental factors playing a significant role in enhancing their entrepreneurial performance.

Recently, Illeris [41] SLT offers a broader lens for understanding learning, positing that it is a multi-dimensional process that includes both external and internal components. The external process involves social interactions with the environment, while the internal process involves cognitive and emotional elements [42,43]. According to Illeris [44], learning is a complex interaction between biological, psychological, and societal elements, and each level—cognitive, emotional, and social—is influenced by the context and environment in which learning occurs. This conceptualization highlights the role of social contexts in shaping learners' understanding and experiences, linking social learning with the development of new knowledge and practices.

The relationship between social learning and innovation is particularly relevant in educational contexts, where both require changes in individual and collective behaviors and attitudes. Innovation in educational practices often involves collaborative and social learning processes, as individuals learn from one another and adapt their behaviors [42]. Just as social learning involves the exchange and negotiation of knowledge within a community, innovation involves the integration of new ideas and practices that may challenge existing norms and practices. In this sense, social learning supports the development of innovative approaches to education, particularly when addressing challenges like mindset transformation or the introduction of new learning technologies [45,46].

In the context of mathematics education, for example, learners' mindsets shape how they approach challenges and engage with learning tasks. The integration of social learning theory into teaching practices could promote a more collaborative, growth-oriented environment, encouraging innovation in both instructional strategies and learners' engagement with the subject matter [47]. Therefore, the role of social learning in innovation, especially within educational systems, is essential in promoting more adaptable and resilient mindsets, ultimately leading to better long-term outcomes in learners' academic achievements [48,33].

# 3. Methods

## 3.1. Research design

This study is grounded in a constructivist research paradigm, acknowledging that knowledge and innovative mindsets are actively constructed through social interactions and shared experiences. This paper explored the experiences of STEM college students in Biliran Province that reflect their innovative mindsets in an academic setting. This paper discussed the context of social learning and how this interacts with the innovativeness of college students in STEM fields within this locale. Exploratory studies answer questions or understanding phenomena by uncovering patterns and insights [49,50]. In social sciences, such studies follow systematic approaches to analyze and document social or psychological elements [50,51]. These studies adhere to structured and organized procedures, allowing researchers to recognize primary patterns and document elements within social or psychological phenomena [50,52]. This approach enhances understanding and facilitates hypothesis generation, which forms the basis for subsequent investigations [53,54]. Despite critiques regarding their perceived lack of scientific rigor, exploratory research is recognized for its ability to efficiently gather preliminary data and deepen understanding of the research problem [55,56]. Such studies often bridge gaps in existing knowledge, enabling researchers to approach a problem with an open-ended methodology that values inquiry and observation over definitive conclusions [57]. As a result, exploratory studies not only provide preliminary insights but also contribute to broader theoretical development and practical applications in various disciplines [58,59].

## 3.2. Participants and sampling

In exploratory studies, sampling often involves small, focused groups to enable a detailed examination of key variables and their interactions [57]. These studies typically feature limited sample sizes, with the number of participants determined by their relevance to the research questions [59,48]. Tuckett [60] recommended using 12 to 20 data sources to capture diverse perspectives without overloading the study with too many participants, which could dilute the focus and complicate the analysis unnecessarily. Purposive sampling is commonly used in such studies, allowing researchers to select participants deliberately based on specific attributes or experiences relevant to the research [59,61]. This non-probability technique offers flexibility, enabling adjustments to sampling criteria as new concepts emerge during the study [58].

In sampling the STEM students from a higher education institution in Biliran Province, online purposive sampling [62] was conducted through open-ended Google Forms survey. Three major sampling characteristics were considered: (1) students' course, (2) currently enrolled in Academic Year 2024-2025, and (3) demonstrated academic innovativeness of any sort. These specific inclusion criteria ensured that participants possessed the necessary information power to provide deep insights into the phenomenon of innovation. Out of 112 college students who responded to the survey, 16 were interviewed for further analysis. Data saturation was monitored during this process, with recruitment ceasing once no new themes emerged.

The final sample included 8 males and 8 females, ensuring gender balance. Participants ranged in age from 18 to 22 years and were enrolled in diverse courses including Engineering, Computer Science, Architecture, Mathematics, and Physics. Their Grade Point Averages (GPA) ranged from 1.34 to 2.00 (where 1.00 is the highest), reflecting a high level of academic competence suitable for discussing successful innovation strategies.

### 3.3. Instrumentation

A semi-structured interview guide was developed to gather the responses from the participants. In qualitative research, the development of interview guide questions is a critical component of the data collection process, ensuring that it is both systematic and adaptable to the evolving nature of the research. The first step in this process is the clear identification of the research objectives, ensuring that the interview questions are directly aligned with the study purpose and the context in which the research takes place [63]. The next phase involves gathering relevant background information that aids in the construction of the interview questions. This can include reviewing existing literature, consulting with experts in the field, and understanding the experiences and perspectives of the target population. Such preparatory work informs the crafting of questions that are both comprehensive and designed to encourage reflective, open-ended responses from participants [64,65]. The primary objective is to formulate questions that elicit comprehensive insights into the phenomenon under investigation, thereby enabling the researcher to obtain detailed, narrative responses that facilitate a deeper understanding of the subject matter [66,67]. A key feature of semi-structured interviews is their flexibility, which allows interviewers to adapt the questioning based on the participants' answers. This is crucial for uncovering deeper insights and exploring new, unanticipated topics as they emerge during the conversation. The interviewer has the freedom to ask follow-up questions, seek clarification, and probe into areas that might not have been foreseen at the outset [68]. This flexibility ensures that the data collection process remains dynamic and responsive to the flow of conversation, making it especially useful in exploratory studies where the phenomenon being studied is not fully understood [63]. Before finalizing the interview guide, pilot testing is an essential practice to assess the clarity, comprehensibility, and relevance of the questions. Pilot testing typically involves a small sample from the target population, such as college students, who provide feedback on the guide's usability and its ability to prompt the desired responses [66]. The feedback obtained during pilot testing informs revisions to the interview guide, allowing researchers to refine the questions to ensure they are clear, relevant, and aligned with the study's objectives. Seeking input from education professionals and other researchers helps further enhance the clarity and focus of the interview questions, ensuring that they effectively capture the intended information [66]. Table 1 presents the final interview guide that was used in one-on-one interviews.

**Table 1.** Interview guide questions

| Research Questions | Questions |
|---|---|
| What innovative skills do STEM students identify as essential for their academic and professional success? | 1. What specific innovative skills do you believe are crucial for your success in your chosen STEM field?<br>2. Can you provide examples of how you have applied these innovative skills in your academic work or projects?<br>3. How do you perceive the relationship between innovative skills and problem-solving abilities in STEM disciplines?<br>4. In what ways do you think your educational experience has helped you develop these innovative skills?<br>5. Are there any skills you feel are currently underemphasized in your curriculum but are vital for your future career in STEM? |
| How do higher education learners perceive the role of the education in developing their innovative skills? | 1. How would you describe the role of your current educational program in fostering your innovative skills?<br>2. Can you share specific instances where your coursework or projects have contributed to your development of innovative skills?<br>3. What teaching methods or approaches do you think are most effective in promoting innovative thinking within your education?<br>4. How do you believe collaboration with peers impacts the development of your innovative skills in an educational setting?<br>5. Are there any aspects of your education that you feel could be improved to better support the development of your innovative skills? |

## 3.4. Data gathering procedure

Conducting interviews in qualitative research is essential for obtaining in-depth, narrative data that reflects participants' lived experiences and behaviors [69,70]. Semi-structured interviews, often used in phenomenological research, provide the flexibility needed to explore key themes while also adapting to the participant's responses [71,72]. The process begins with establishing clear research objectives and selecting participants that align with the study's goals [73].

Ethical considerations were strictly observed. Researchers ensured transparency by explaining the study's purpose, confidentiality, and data usage to participants, encouraging trust and ethical integrity [72]. Informed consent was obtained from all participants, and anonymity was guaranteed by removing personal identifiers from the transcripts. Throughout the interview, it is crucial to maintain a natural conversational flow, encouraging participants to share their experiences freely while guiding the conversation with thematic questions and follow-ups [74]. Cultural sensitivity and linguistic considerations are necessary to minimize barriers and ensure effective communication [75]. Finally, flexibility in the process is vital for deepening insights, as participants should be allowed to lead the conversation, enabling the researcher to explore new avenues [76]. The interviews are typically audio-recorded for accuracy, and preliminary notes are taken to capture essential points for later analysis [77].

## 3.5. Data analysis

Narratives from one-on-one interviews were the primary data of this study. In conducting reflexive thematic analysis using an inductive approach for an exploratory study, researchers engage with the data by identifying patterns within participants' experiences, opinions, and behaviors, as revealed through their narratives [73,78]. The inductive method is key to this process, as it focuses on deriving themes directly from the data, without preconceived theoretical frameworks, ensuring the analysis is deeply connected to participants' lived experiences [79]. Reflexive thematic analysis emphasizes the researcher's subjectivity, acknowledging that their personal perspective influences the interpretation of data. This does not equate to bias but rather ensures the analysis remains responsive to the research question and context [80,81]. The researcher's engagement is seen as an integral part of the analysis, with the flexibility of this method allowing the study to evolve as new themes emerge from the data [82].

The analysis follows a systematic, iterative six-phase process outlined by Braun and Clarke [79], which involves familiarizing oneself with the data, generating codes, identifying themes, refining these themes, and ultimately producing the final report. For example, the raw participant quote "I started experimenting with different techniques... thinking beyond them," was initially labeled with the code "Experimentation," which later contributed to the development of the theme "Application." This process is flexible, with researchers revisiting earlier stages as new insights emerge [78]. The inductive approach enhances the method's ability to uncover unanticipated themes, thus contributing to a more grounded understanding of the research phenomenon [83,84]. The use of thematic analysis in an exploratory study enables researchers to explore shared experiences and social phenomena in a comprehensive and authentic manner [50,78]. The study ensured that the data is analyzed in a way that remains closely tied to the participants' narratives, with flexibility allowing the exploration of both explicit and implicit meanings [78,84]. This methodological approach supports an open-ended investigation, allowing for the development of hypothesis grounded in the lived experiences of participants [79].

To ensure the credibility of the findings, member checking was employed; participants were given the opportunity to review their transcripts and the emerging themes to confirm alignment with their lived experiences. Additionally, the analysis included a search for negative cases—instances where students strictly adhered to traditional methods without innovating—to challenge the emerging themes. While the majority of narratives supported the core themes of flexibility and creativity, these comparisons helped refine the boundaries of the "Innovative Mindset" framework, ensuring it reflected a genuine deviation from standard academic behaviors rather than just high performance.

## 4. Results

Question 1: What innovative skills do STEM students identify as essential for their academic and professional success?

The analysis revealed that Flexibility, Creativity, and Knowledge are the core components of an innovative mindset as perceived by STEM students. Participants emphasized that flexibility is vital for navigating the rapid evolution of technologies, such as mastering new programming languages and adopting industry-standard tools. The ability to approach challenges with fresh ideas while leveraging advanced technologies highlights the need for a mindset of continuous learning in dynamic fields like engineering and technology. Similarly, creativity was framed as a problem-solving engine, enabling students to devise unique and unconventional solutions to coding, design, and optimization challenges. From interpreting constraints in group projects to improving system efficiency, a creative mindset allows individuals to innovate beyond traditional methods. Students recounted experiences where their creative approaches facilitated successful outcomes, reinforcing the importance of pushing boundaries to enhance scalability, resource management, and system performance. Lastly, knowledge—specifically a deep understanding of emerging technologies such as AI, machine learning, and cybersecurity—was identified as the necessary foundation for innovation. This competency extends beyond textbook learning; students highlighted the importance of applying fundamental principles to new contexts, such as addressing site-specific engineering challenges or incorporating sustainable materials. Consequently, innovative skills were perceived as the bridge between theoretical knowledge and practical application, facilitating smarter, more efficient solutions to complex problems. These themes illustrate that STEM students view innovation as a dynamic interaction of adaptability, ingenuity, and expertise.

Theme 1: Flexibility

The theme of Flexibility centers on the student's capacity to adapt to ever-changing technologies, techniques, and industry demands. The data indicates this skill is integral to maintaining an innovative mindset, rooted in adaptability and a commitment to continuous learning. Participants noted that the rapid pace of the STEM landscape requires them to adapt quickly to new technologies and master new programming languages to remain competitive. This adaptability represents a proactive approach to embracing change. Flexibility empowers individuals to respond effectively to unforeseen challenges, particularly in fields like engineering and technology where tools and methodologies constantly evolve. By viewing change as an opportunity rather than a barrier, individuals position themselves to explore uncharted solutions and methodologies.

> "The ability to adapt quickly to new technologies and learning new programming languages on the fly is also important. Flexibility and a mindset of continuous learning are critical because tech is constantly evolving."

The link between flexibility and innovation is further illuminated by how adaptability enables the integration of fresh ideas into sustainable and efficient infrastructure projects. Participants explained that true adaptability involves not only keeping pace with the latest technologies but also applying them creatively to solve real-world problems. This application relies on a combination of technical knowledge and the willingness to experiment.

> "With the growing demand for sustainable and efficient infrastructure, it's important to approach challenges with fresh ideas while being able to use the latest technologies. Also, being adaptable in applying new software or techniques is essential, especially when industry tools keep evolving."

Moreover, a mindset of continuous learning was consistently identified as a driver of flexibility. To cultivate innovative solutions, STEM students must remain open to acquiring new skills and redefining traditional methods. This openness allows for the creation of solutions tailored to evolving industry needs, such as developing sustainable infrastructure or employing advanced software.

> "With the growing demand for sustainable and efficient infrastructure, it's important to approach challenges with fresh ideas while being able to use the latest technologies."

In summary, flexibility serves as a cornerstone of the innovative mindset, enabling individuals to adapt, learn, and apply knowledge dynamically. It allows STEM students to navigate a rapidly changing environment with confidence, fostering the capacity to approach challenges creatively and effectively.

Theme 2: Creativity

Creativity as the ability to devise unique solutions and approach problems from new angles, distinguishing it as a primary driver of the innovative mindset. The narratives consistently described how creativity allows students to overcome challenges by thinking beyond conventional methods. Participants emphasized that creativity is critical for addressing the complexity of STEM problems, where traditional solutions often are insufficient. They associated creativity with an openness to trying something new, even if the approach initially appears unconventional. This willingness to experiment was identified as a catalyst for innovation, enabling individuals to approach problems dynamically.

> "Also, creativity in approaching problems—like finding unique solutions to coding challenges—helps set you apart in this field."

The data highlights that finding unique solutions to issues, such as coding challenges or design constraints, distinguishes successful students in STEM fields. This suggests that creativity involves pushing boundaries to optimize outcomes rather than simply solving a problem. For instance, participants recounted using creativity during group projects, such as developing a model bridge with limited resources, where their ability to interpret constraints innovatively led to successful results. These experiences underscore the value of thinking unconventionally.

> "In my coursework, I've applied these skills primarily through group projects and design challenges. For example, during a structural design class, we had to develop a model bridge using limited resources. The team had to be creative in interpreting the constraints, which led to a successful project outcome."

> "When you're trying to optimize code or improve a system's efficiency, having a creative mindset opens up possibilities. Instead of just going with the obvious solution, you can find ways to push the limits, whether it's in terms of speed, scalability, or resource management."

The relationship between creativity and an innovative mindset is evident in the participants' emphasis on exploring unconventional possibilities. In tasks like optimizing code or improving system efficiency, relying solely on traditional solutions often falls short. Instead, a creative mindset enables students to push the limits of feasibility, enhancing outcomes in terms of speed, scalability, and resource management.

> "Innovative skills are essential for approaching problems from new angles and devising creative solutions. In STEM, problem-solving often involves thinking beyond conventional methods, and innovation drives that process."

> "In STEM, you're constantly faced with complex problems, and traditional solutions don't always work. Having innovative skills means you're not afraid to try something new, even if it seems unconventional at first."

Creativity shapes the innovative mindset by enabling STEM students to approach challenges with originality. It encourages them to explore alternative solutions, reinterpret constraints, and enhance problem-solving effectiveness in complex environments.

Theme 3: Knowledge

Knowledge emerged as a theme emphasizing the importance of a strong understanding of emerging technologies and the ability to apply basic principles in novel ways. Participants described how comprehensive and up-to-date knowledge empowers them to approach problems with smarter and more effective solutions. They underscored the value of expertise in areas such as AI, machine learning, and cybersecurity for addressing complex STEM challenges. This indicates that innovation requires not just technical skills but also the capacity to leverage emerging technologies to enhance problem-solving. By staying informed about technological advancements, participants are able to devise solutions that are both creative and practical.

> "A strong understanding of emerging technologies like AI, machine learning, and cybersecurity."

> "Innovative skills and problem-solving go hand in hand in STEM. It's not just about solving problems but finding better, smarter ways to do so."

The connection between knowledge and an innovative mindset is particularly evident in fields like civil engineering, where participants encounter problems that often lack clear, textbook solutions. They highlighted that innovation involves adapting basic principles to new contexts, such as challenging site conditions or the integration of sustainable materials. This approach focuses on reinterpreting and applying existing knowledge to meet evolving demands rather than reinvention.

> "In civil engineering, many of the problems we face don't have clear, textbook solutions. You need to be innovative to adapt basic principles to new contexts—whether it's a challenging site condition or incorporating sustainable materials. It's less about reinventing the wheel and more about using what you know in new and efficient ways."

Furthermore, participants noted that knowledge acts as a foundation for exploring better, smarter ways to solve problems. It allows them to approach issues with confidence, ensuring their solutions are efficient and aligned with the latest industry standards. This proactive use of knowledge to anticipate and solve challenges reflects the essence of an innovative mindset.

> "When you have clear theoretical knowledge, it helps you develop an effective innovative mindset. Knowledge will keep you grounded and clear to your purpose."

Ultimately, knowledge supports the innovative mindset by equipping individuals with the tools to adapt, innovate, and apply their expertise effectively. It encourages STEM students to bridge theory and practice, addressing problems with ingenuity and forward-thinking solutions.

Question 2: How do higher education learners perceive the role of education in developing their innovative skills?

The findings of this study explored higher education learners' perceptions of how education develops their innovative skills, highlighting three key themes—simplification, application, and collaboration. These themes underscored the role of education in shaping students' ability to think critically, creatively, and practically in both academic and professional contexts. Learners emphasized simplification as a crucial aspect, describing how educators' ability to break down complex concepts into manageable steps facilitated their problem-solving capabilities. This process not only enhanced understanding but also encouraged students to adopt similar strategies when tackling their own challenges. The theme of application highlighted the importance of hands-on, real-world experiences in developing innovative skills. Students noted that project-based and problem-based learning allowed them to bridge theoretical knowledge with practical challenges, encouraging them to think critically and creatively. Whether optimizing algorithms, using design software like AutoCAD, or engaging in internships, these opportunities enabled learners to translate abstract ideas into actionable outcomes, sharpening their technical skills and supporting creative experimentation. Finally, collaboration emerged as an essential driver of innovation. Learners recognized the value of teamwork and communication skills in generating new ideas and perspectives. Collaborative projects, such as designing interactive lessons or solving real-world problems as a team, exposed students to diverse viewpoints and methods, facilitating a collective approach to innovation that mirrored professional STEM environments.

Theme 1: Simplification

Simplification illustrated how breaking down complex problems into manageable components supported the development of students' innovative mindsets. This process was deeply rooted in creative problem-solving and metacognitive skills, empowering learners to identify patterns, approach challenges systematically, and adapt strategies for effective solutions.

> "Teaching math effectively goes beyond just knowing how to solve equations; it's about finding creative ways to break down complex ideas so that students can truly understand them."
>
> "For example, breaking down a complicated problem often requires thinking outside the box, which can reveal patterns or solutions that aren't obvious at first. In teaching, innovative problem-solving is necessary to present ideas in multiple ways so every student can find an entry point to understanding."

Teachers engaged in cognitive modeling by breaking down the process of simplification, which students then internalized and applied to their own tasks. This alignment reflects the principles of social learning, where learners developed their innovative capabilities by observing and imitating the techniques demonstrated by their teachers. For instance, students learned to think backwards and reassess their approaches to identify errors, a strategy that reinforced their ability to tackle problems creatively and analytically.

> "One of the most important aspects of learning is the introduction of simplification process. For me, when teachers are good in simplifying the process, I also be able to adapt that when dealing with problems."
>
> "For example, when it comes to laboratory activities if I face problems in my tasks, I always think backwards and assess what I did wrong. This helped me solve the problems I face."

Simplification was also linked to the transference of innovative problem-solving skills. By presenting complex concepts in multiple ways, teachers enabled students to find personalized entry points to understanding. This adaptability supported cognitive flexibility, a critical component of innovation, as students began to see problems from diverse perspectives and experiment with unconventional solutions. The iterative process of refining and simplifying ideas promoted a growth-oriented mindset, preparing students to innovate within real-world contexts.

> "Having an effective simplification method involves strong metacognitive skills. For me, I learn this from my teacher who knows how to simplify complex problems and explain it bit by bit. This helps me solve mine too."

Teachers' abilities to simplify complex ideas served as a model of innovation, demonstrating how creativity could be applied to intellectual challenges. This process not only encouraged independent problem-solving but also emphasized the value of learning through social contexts, where shared strategies and insights enriched students' understanding. Fundamentally, innovation thrived in environments where complex problems are approached with clarity, creativity, and collaborative learning, cultivating students' abilities to navigate challenges with confidence and ingenuity.

Theme 2: Application

Application focused on how hands-on experiences and real-world problem-solving significantly contributed to the development of students' innovative mindset. Students found that practical application, whether through project-based learning, problem-based learning, or real-world assignments, encouraged them to apply theoretical knowledge in dynamic and creative ways. This process highlighted the importance of translating classroom learning into actionable solutions, which is essential for cultivating innovation.

> "I think there could be more emphasis on practical application of these innovative methods in real classroom settings. I've learned a lot theoretically, but it's in the hands-on work, like student teaching, that I really get to apply and refine these skills."

> "My educational experience has definitely pushed me toward developing these innovative skills, mostly through hands-on projects and problem-based learning."

Students noted that working on real-world problems, such as coding assignments, design projects, and lab work, required them to move beyond theoretical understanding and explore novel solutions. This approach allowed them to refine their creative and critical thinking skills, as they were prompted to experiment with different methods and techniques to solve challenges where there was no obvious or pre-existing solution. The challenge of addressing complex problems in real-world contexts encouraged students to be more flexible and open-minded in their problem-solving approach, which is a core aspect of innovation.

> "In coding assignments, for example, we're often given real-world problems to solve, and it's up to us to figure out the best approach. These projects have helped me think more critically and creatively about how to apply what I'm learning to situations where there's no clear solution."

> "As a previous STEM student, courses like programming, software development, and systems analysis have been instrumental in building my innovative skills. Projects that required practical application of theoretical knowledge have been particularly helpful."

> "Lab work, design projects, and internships all require us to think beyond just the theoretical knowledge."

Through the iterative process of applying theoretical knowledge to practical challenges, students honed their technical skills while developing an ability to think beyond established methods. For example, in courses like algorithms, students were encouraged to experiment with new techniques, ultimately leading to more efficient solutions. This emphasis on experimentation and innovation nurtured a mindset that valued creative problem-solving and adaptation in the face of uncertainty.

> "I've also had opportunities to use design software like AutoCAD and Revit, which forces me to translate ideas into actionable plans, sharpening both creativity and technical skills."

> "One instance where my coursework really helped with developing innovative skills was in my algorithms class. We were tasked with optimizing a basic sorting algorithm. Initially, I followed the standard approach, but then I started experimenting with different techniques and data structures, which led me to discover more efficient ways to handle specific datasets. It wasn't just about learning existing algorithms, but about thinking beyond them and trying new ideas."

> "I find that project-based learning and problem-based learning are the most effective teaching methods when it comes to innovation. When we're given a real-world problem and asked to solve it, it forces us to be creative and think critically."

> "Theoretical lectures are useful, but it's the practical challenges that really develop innovative thinking."

Theme 3: Collaboration

Collaboration highlighted the significant role of teamwork and communication in developing an innovative mindset among students. Collaboration, particularly in diverse groups, allowed individuals to engage with different perspectives, which proved to be essential in facilitating creativity and problem-solving skills. Working alongside peers encouraged students to think beyond their own ideas, leading to the generation of new ideas and the exploration of innovative solutions. This exposure to various viewpoints within a collaborative environment is a core element of social learning, as it emphasizes the collective exchange of knowledge and ideas through observation and shared practice.

> "One thing that I feel is currently under emphasized in the curriculum is soft skills, particularly communication and teamwork. In the real world, you're not just coding in isolation. You're a part of a team, and being able to clearly explain your ideas and collaborate effectively is crucial. These are skills that are sometimes overlooked in favor of technical knowledge, but they are essential for a successful career in STEM."

> "One standout project was creating a collaborative group lesson for a high school-level math class. Teachers had to design an entire session around an algebraic concept using interactive and digital tools."

Consistent with social learning theory, people learn not only through direct experience but also by observing and interacting with others. In the context of collaboration, students observed how their peers approached their problems, communicated their ideas, and contributed to shared goals. This process allowed them to model effective behaviors, refine their own strategies, and adapt their communication skills, which are essential components of an innovative mindset. Working in teams, students were also able to practice soft skills, such as communication and teamwork, which are crucial in the real world, particularly in STEM fields. These soft skills were sometimes overlooked in favor of technical knowledge, but the collaborative setting emphasized their importance in the development of innovative skills. In turn, students who engaged in group work were not only able to apply their knowledge more creatively but were also encouraged to think critically and collaboratively, thereby enhancing their ability to solve complex problems.

> "Collaboration with peers has been invaluable in developing my innovative skills. When you're working with others, especially those with different perspectives, you get exposed to new ideas and ways of thinking."

> "Collaboration with peers has been one of the best ways to develop my innovative skills. Different perspectives often lead to new ideas I wouldn't have thought of on my own."

Through this social learning process, students developed a growth mindset, where they understood that innovation often arises from diverse ideas and the ability to work together. Finally, collaboration supported an environment that nurtured the creativity and critical thinking necessary for innovation.

## 5. Discussion

The rapid advancement of technology in STEM fields underscores the need for students to quickly adapt and commit to lifelong learning [85]. Automated technologies, such as intelligent tutoring and data analytics, have significantly elevated learning outcomes in STEM education [86,87]. He et al. [88] noted that problem-solving is vital for cultivating creativity and innovation among engineering students, who must communicate effectively and approach issues with a novice's openness rather than an expert's rigidity. This can be facilitated through non-traditional educational tools like dramatization, videos, and interactive models. Participants shared how unconventional problem-solving approaches allowed them to navigate academic projects creatively, emphasizing the importance of thinking beyond conventional solutions [89,90]. Adeoye et al. [91] emphasized the importance of encouraging innovation and creativity by prioritizing problem-solving skills, which are key to overcoming challenges in academic and professional settings.

Students recognized that innovative thinking—often involving collaboration, critical analysis, and adaptation—is essential in effective project development. Being innovative involves introducing or creating new ideas, methods, products, or solutions that are original, effective, and often transformative [92,93]. Hence, an innovative mindset reflects the ability to approach problems with creativity, open-mindedness, and a willingness to explore new ideas and solutions [94]. This paper observed that the innovative mindset in STEM programs involved flexibility, creativity, and knowledge. Early studies on innovativeness indicated that creativity and innovation are highly related concepts [95]. However, this study nuances established frameworks of 21st-century skills [26]. by highlighting that distinct from general creativity, STEM innovation specifically requires flexibility (adaptability to technical evolution) and knowledge (theoretical grounding). In entrepreneurship, creativity extends beyond the development of new products; it also involves discovering relevant ways to add value for consumers, enhance services, or streamline work processes [96,97]. This paper adds to this understanding that innovation in STEM also requires flexibility (being adaptable) and knowledge (having intellect).

Innovation is a learning process in which an innovator discovers effective, value-creating solutions to problems, and by increasing students' awareness of this process, they can better understand how innovation works [98]. One student noted that "knowledge will keep you grounded and clear to your purpose." Another student said that "flexibility and a mindset of continuous learning are critical because tech is constantly evolving." For innovation to be successful, students need not only creativity but also the knowledge to understand problems and the flexibility to adapt to new and evolving solutions. In business, research indicates that the ability to adapt plays a key role in achieving both long-term competitive advantage and success in the development and commercialization of new products [99]. This concept is similarly observed in the development of an innovative mindset within STEM education, where students' capacity for flexibility and adaptability helps them overcome challenges and generate solutions in rapidly evolving fields. As students engage with advancing technologies and collaborate in diverse settings, their adaptability, knowledge, and creativity allow them to make the most of new tools, methods, and ideas, shaping their development as innovative thinkers and future professionals in their fields.

Social learning processes play a critical role in instilling an innovative mindset among STEM students. Albert Bandura's social learning theory posits that individuals acquire new behaviors through the observation and imitation of others [15]. It highlights the significance of learning through observation, where people gain knowledge, skills, attitudes, and beliefs by watching the actions of others and noting the outcomes, which then leads to the replication and adoption of those behaviors [100]. This paper observed that developing an innovative mindset among STEM students required strong classroom environments. Acar and Tuncdogan [101] suggest that a collaborative, open-ended, and exploration-driven inquiry approach could successfully promote innovative behavior in students.

Teachers contribute significantly to this process by acting as cognitive models. When teachers demonstrate how to simplify complex topics, they are not merely transmitting information but are modeling the cognitive strategy of decomposition. In the context of problem-based learning, one student reflected on his classroom experience stating, *"Initially, I followed the standard approach, but then I started experimenting... It wasn't just about learning existing algorithms, but about thinking beyond them and trying new ideas."* Teachers who actively engage in modeling innovative behaviors—such as thinking aloud when solving problems or admitting error—help students internalize these critical thinking skills. Similarly, teaching innovation demands that educators integrate not only strategies to encourage creative thinking but also approaches for effectively applying new ideas and evaluating their impact [98].

Interestingly, when teachers displayed competence in teaching, such as being able to simplify complex topics, it facilitated the development of an innovative mindset in students, especially in the context of solving their problems. In English education, studies explored how teachers approach the task of simplifying academic texts for non-native English speakers [102], which improve students' understanding [103] and information recall [104]. This paper observed that when STEM teachers used simplification, it encourages their students to use a similar approach when facing problems. For example, one student noted that "*Having an effective simplification method involves strong metacognitive skills. For me, I learn this from my teacher who knows how to simplify complex problems and explain [them] bit by bit. This helps me solve mine too."* This explicitly demonstrates observational learning, where the student mimics the teacher's analytical method to navigate their own independent challenges. Students develop innovative thinking when teachers demonstrate the ability to simplify complex problems and effectively solve them. By breaking down difficult concepts into manageable steps, teachers provide students with clear examples of how to approach challenges, encouraging critical thinking and problem-solving skills. This process not only helps students understand complex ideas but also encourages them to apply creative solutions in their own work. When teachers model these skills, students are more likely to internalize these strategies, building their capacity to innovate and think outside the box when faced with similar problems.

The study emphasized that an innovative mindset involves more than just creativity. It requires flexibility and knowledge, enabling students to adapt to new challenges and generate solutions in rapidly changing technological landscapes. By encouraging students to engage with new tools and methods, teachers can nurture their adaptability and capacity for innovation, preparing them for success in both academic and professional settings. Social learning processes have a role in developing an innovative mindset. Teachers who model creativity, problem-solving, and adaptability not only guide students in their academic pursuits but also inspire them to take risks, experiment with new ideas, and learn from failure. In the classroom, teachers who simplify complex problems and provide clear, manageable solutions can encourage innovation in their students. When educators break down difficult concepts into bite-sized steps and actively engage students in problem-solving, they help students develop critical thinking skills and encourage creative solutions. This process of simplification empowers students to approach challenges with confidence and creativity, ultimately building their capacity for innovation. Generally, the study suggested that adaptive teaching strategies, effective use of technology, and a supportive learning environment is crucial for cultivating an innovative mindset among STEM students.

## 6. Limitations

While this study provides valuable insights, several limitations must be acknowledged. First, as an exploratory pilot, the study relied on a small, purposive sample (n=16) from a single higher education institution in Biliran Province. Consequently, the findings regarding the "Flexibility-Creativity-Knowledge" triad may not be transferable to the broader population of STEM students outside this province or those in different cultural or institutional contexts. Second, the reliance on self-reported data introduces the potential for social desirability bias; students may have overstated their innovative behaviors or perceived skill levels to align with the positive nature of the interview questions. Finally, due to the cross-sectional design, this study captures participants' perceptions of their education but cannot empirically prove a causal link between specific teaching methods (like simplification) and the acquisition of innovative skills. Future research should employ longitudinal designs to track skill development over time and include classroom observations to triangulate self-reported narratives with actual behavioral evidence

## 7. Conclusion

The findings suggest that innovation as perceived by STEM students is not solely a product of creativity, but also requires flexibility, adaptability, and knowledge. It became clear from the participant narratives that innovation in STEM fields is viewed not simply as generating new ideas, but as applying these ideas in ways that are effective, flexible, and aligned with current and future needs. The ability to adapt to new technologies, approaches, and methods was consistently highlighted by students as a vital skill for problem-solving and success in their academic and professional careers.

The study also underlined the importance of social learning processes in nurturing innovation. The data indicates that by observing and imitating the behaviors of teachers and peers, students believe they are able to internalize innovative practices, adopt new problem-solving techniques, and develop their creative potential. Teachers who embrace problem-solving, creative thinking, and risk-taking within their own teaching practices are perceived to provide students with the tools to develop these skills themselves. Similarly, teachers who effectively break down complex concepts into manageable components were reported to allow students to better understand the material and, in turn, apply it more creatively. Simplification in this context does not mean reducing content, but rather making the content more accessible and easier to engage with, which participants felt encouraged them to think critically and solve problems more efficiently.

The study highlighted that an innovative mindset in STEM education can be cultivated through different strategies, including the integration of technology, collaboration, and flexible problem-solving approaches. It is clear that for STEM students to thrive in an environment of rapid technological advancement, they benefit from being encouraged to think creatively, adapt to new challenges, and continually learn and innovate.

This study has several important implications for educators, curriculum designers, and policymakers in the realm of STEM education. The study suggests that developing an innovative mindset in STEM students requires a shift in educational practices toward active modeling and social interaction. Educators must move beyond traditional teaching methods and embrace creative and flexible approaches to problem-solving. This includes the integration of technology and non-traditional educational tools such as videos, dramatization, and interactive models. These tools can help students think beyond conventional solutions and cultivate a mindset of continuous learning and innovation.

Crucially, teachers must not only impart knowledge but also actively model innovative behaviors in their teaching practices. When demonstrating creativity, problem-solving skills, and adaptability, teachers serve as cognitive models, inspiring students to adopt these behaviors and apply them in their own work. Teachers should be encouraged to verbalize their thought processes, take risks, experiment with new methods, and explicitly demonstrate that learning from failure is an essential part of the innovation process.

Further, the study suggests that creating a supportive learning environment is crucial for innovation. A collaborative, inquiry-driven classroom atmosphere that encourages exploration, risk-taking, and learning from mistakes can significantly contribute to the development of an innovative mindset. Teachers should create an environment where students feel safe to experiment, share ideas, and collaborate with their peers.

To maximize the benefits of this social learning, educators should structure collaborative tasks to ensure students actively observe and critique peer strategies, rather than working in isolation alongside one another. This can be achieved through structured group work, problem-based learning, and other interactive learning activities that promote observational learning and collaboration.

Finally, it is important to reiterate that as an exploratory pilot study, these findings represent the lived experiences of a specific group of STEM students in Biliran Province. Future research should build upon these initial insights to empirically test the effectiveness of these pedagogical strategies across broader populations.

## Conflict of interest

The authors declare no conflict of interest

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