

FOSTERING CREATIVE THINKING IN ENTREPRENEURSHIP AMONG RURAL STUDENTS THROUGH SOCIO-SCIENTIFIC ISSUES AND DESIGN THINKING INTEGRATION IN SCIENCE EDUCATION

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Abstract. *Previous studies have demonstrated that the socio-scientific issue approach (SIA) and design thinking (DT) can inspire creative thinking in science learning. However, the way in which the integration of SIA and DT fosters creative thinking in entrepreneurship (CTE) among rural secondary school students during science learning remains unclear. To address this gap, a learning module was developed to explore this integration and examine its implementation challenges. A qualitative research design, using a case study approach with purposive sampling, was employed. Individual semi-structured interviews were conducted with nine tenth-grade students from three rural secondary schools in Tawau, Sabah, Malaysia. Students shared their perspectives on the implementation and challenges of the SIA-DT learning module. The interview findings suggest that students believe the SIA-DT method fosters CTE, despite some persistent challenges. This approach has the potential to enhance holistic thinking, critical thinking, transformative learning, systematic inquiry, creative problem-solving, value-based reasoning, strategic planning, and market-driven innovation. Overall, the SIA-DT method shows promise in shaping the next generation of creative entrepreneurs among rural secondary school students.*

Keywords: *creative thinking, entrepreneurship, design thinking, rural secondary schools, socio-scientific issues approach*

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Introduction

Creative thinking is essential for young entrepreneurs because it helps them generate new ideas, solve problems, and gain a competitive advantage. Creative thinking is generally defined as the ability to generate new and useful ideas (Amabile, 1997) and often emerges from blending existing elements in new ways. The fusion of creative ideas can open up new opportunities, including advancements in products, services, processes, technologies, and organizational management. Therefore, creative thinking and entrepreneurship are inseparable, as individuals and teams that generate creative ideas through a repetitive process can create new opportunities for launching ventures (Ward, 2004). When individuals and teams create new products and processes for an organization to benefit the firm and its stakeholders, they are engaging in innovation (Wong et al., 2009).

Today's industrialized world recognizes that creative thinking enables the discovery and exploitation of new opportunities, making firms more competitive and innovative (Fillis & Rentschler, 2010). Consequently, interest in fostering school students' creative thinking in the classroom is growing worldwide (Katz, 2003; Kuratko, 2005; Pittaway & Cope, 2007). Nurturing school students to become young entrepreneurs is crucial, as it provides them with real-world business experience, equipping them with essential skills for future careers.

Creative thinking in entrepreneurship (CTE) can be defined as an individual's ability to create improved products, services, processes, or practices that add value to the market compared to what previously existed (Dayan et al., 2013). CTE can also be defined as the generation of unusual or unique ideas that create value in the market (Perry-Smith & Coff, 2011). The application of CTE can help students identify opportunities to introduce new ideas to the market, foster a culture of innovation, and encourage team or organizational openness that supports innovation in developing new products and services.



Thus, applying CTE through learning and facilitation activities (LF) and experience in school will equip students to think like entrepreneurs, enabling them to identify market opportunities and explore appropriate ways to capitalize on them (Bacigalupo et al., 2016). Students with CTE will consistently demonstrate innovation in solving problems (Nadelson et al., 2018). In other words, the application of CTE in LF in the classroom can cultivate human capital capable of innovating new ideas or products by leveraging available opportunities. Therefore, an approach needs to be identified, and we should explore how this approach can develop CTE among secondary school students, as well as the challenges faced.

Literature Review

Socio-scientific Issue Approach and Design Thinking Model

Socio-scientific issues (SIs) are public debates that involve complex, real-world problems grounded in scientific principles and ideas (Zeidler, 2014). These issues add a new dimension to the learning experience, potentially transforming its nature, meaning, and perceived importance (Sadler & Zeidler, 2009). Science education researchers recognize SIs as a valuable, active context that connects classroom learning with the broader community (Topçu et al., 2018). The Socio-scientific Issues Approach (SIA) shares characteristics with several pedagogical methods, such as project-based learning (Badeo & Duque, 2022), case-based learning (Yadav et al., 2007), and context-based learning (Bennett & Lubben, 2006). Each of these approaches is rooted in the principle that learning gains depth and relevance when connected to a meaningful context (Sadler et al., 2017). SIA leverages situated learning theory (Lave & Wenger, 1991) by embedding science education within real-life contexts, fostering collaborative discussion, and enabling students to explore science within societal and cultural frameworks. Additionally, constructivist theory supports the SIA approach by emphasizing that students learn best when they can relate new concepts to real-world issues, thereby making science more relevant and impactful (Piaget, 1954). Zeidler (2016) conducted a study on the use of the socio-scientific issues approach (SIA) in STEM teaching and learning. It was found that students who can connect science with society are better equipped to address socio-scientific issues and potentially create solutions to these challenges.

Design thinking is a problem-solving process that starts by defining specific goals to tackle challenges (Razzouk & Shute, 2012). It encourages creative, outside-the-box thinking for complex problems (Clarke & Bell, 2018) and addresses ambiguous issues (Buchanan, 2001). This approach is applied to human-centered, real-world problems, enhancing product innovation in business and management (Butler et al., 2023; Foster, 2021).

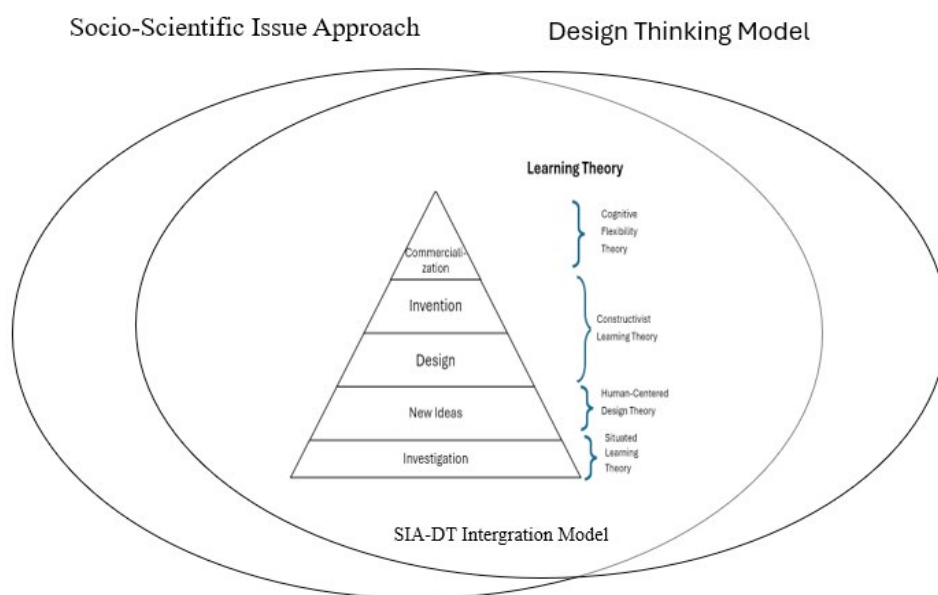
The Design Thinking model aligns with cognitive flexibility theory, emphasizing the importance of adapting to new perspectives and changing information (Spiro & Jehng, 1990). Learners are encouraged to remain open to different viewpoints, which is crucial for navigating complex problems and refining solutions based on ongoing feedback. Additionally, the Design Thinking model aligns closely with the principles of human-centered design theory (Norman, 2013), emphasizing the importance of creating solutions through a deep understanding and prioritization of the needs, contexts, and experiences of the people who will use them.

As a pedagogical approach, Design Thinking (DT) uses socio-scientific issues as a learning context, focusing on complex, unstructured problems without clear solutions (Zeidler, 2014). Integrating DT within the SIA framework not only enhances students' scientific knowledge but also prompts them to consider the moral and societal implications of scientific issues (Sadler & Zeidler, 2005; Zeidler, 2016; Zeidler & Nichols, 2009). This integration allows students to evaluate current issues, analyze evidence, and discuss ethical questions, underscoring the need for a model that combines SIA and DT to foster creative thinking in entrepreneurship (CTE)

Theoretical Framework

Swartz and Parks (1994) introduced a model for integrating teaching about thinking and the elements of thinking to encourage students to engage more actively and explicitly. In this integration method, the thinking skills to be taught are identified first and then taught simultaneously with the lesson content. This study highlights the integration model of Swartz and Parks (1994) through the integration of socio-scientific issues approach (SIA) and Design Thinking (DT) model in the development of the theoretical framework of the study, as illustrated in Figure 1 and detailed in the developed SIA-DT module.



Figure 1*The theoretical framework of the study*

The SIA-DT module comprises five steps starting from Investigation, New Ideas, Design, Invention, and Commercialization. These five steps are adapted from the entrepreneurial thinking learning model by Buang et al. (2009). In the first stage, students conduct an investigation focusing on socio-scientific issues by asking questions to understand the issue, its relationship with science, and community sensitivity. This step corresponds with situated learning theory (Lave & Wenger, 1991), where students are involved with real-life contexts, fostering collaborative discussion, and enabling students to explore science within societal and cultural frameworks. The second stage provides a platform for students to actively engage in exploring new ideas to solve problems while considering user needs. This step corresponds with human-centered design theory which emphasizes designing solutions that meet the needs, preferences, and behaviors of the end user. The third stage encourages students to synthesize their ideas by designing new products through sketches. The fourth stage involves students translating sketches into product forms. The products are created using locally sourced raw materials deemed appropriate for production. The third and fourth step mirrors constructivist learning theory, as participants learn and adapt by testing ideas and building prototypes.

In the fifth stage, students test the product by obtaining feedback from users and considering how to commercialize it. This stage includes branding, pricing, determining distribution channels, and marketing channels, as well as making promotions through digital marketing platforms compatible with Industry 4.0. At this stage, students apply basic digital marketing skills through the development of products, pricing, placement, and promotions to generate income. This stage aligns with cognitive flexibility theory which encourages learners to apply knowledge in multiple ways across different contexts rather than relying on rigid, single-path solutions. This helps them adapt knowledge to solve complex and novel problems.

The module, supported by this theoretical framework, enhances students' ability to foster creative thinking in entrepreneurship (CTE) while learning science in rural secondary schools.

Research Questions

Previous studies have demonstrated that incorporating design thinking into the STEM learning process can enhance creative thinking (Kelley & Kelley, 2023; Khalil et al., 2023). However, the potential of integrating the Socio-Scientific Issues Approach (SIA) with the Design Thinking (DT) model to foster students' creative thinking in entrepreneurship (CTE) while learning science in rural secondary schools—and the challenges students face in this context—remains underexplored. Therefore, this study was conducted to address the following research questions:

1. In what ways can the implementation of the SIA-DT integration method foster rural secondary students' creative thinking in entrepreneurship?
2. What challenges are associated with implementing the SIA-DT integration method to foster students' creative thinking in entrepreneurship?

Research Methodology

Design

This study employed a qualitative approach with a case study design. A qualitative case study enables researchers to explore phenomena in depth, uncovering rich, contextual details (Yin, 2018). It emphasizes participants' perspectives, ensuring their voices are authentically represented (Creswell & Poth, 2018). By situating findings within real-life contexts, it enhances ecological validity (Lincoln & Guba, 1985). Additionally, the research process allows new themes and patterns to emerge organically (Braun & Clarke, 2006). As a result, insights gained from qualitative case studies can contribute to theory development by refining the proposed SIA-DT integration model.

This study used a purposive sampling method to select participants who have specific characteristics, knowledge, or experiences about learning science using the SIA-DT integration method. By targeting individuals with specific characteristics, researchers can focus their time and resources on collecting information that directly contributes to more insightful and specific data that aligns closely with the research aim (Patton, 2015).

Sample

A total of nine participants (five females and four males, aged 17 years) were selected from three rural secondary schools, Tawau district, Sabah, Malaysia, with three students from each school. Creswell (2013) suggests that a sample size of 5-25 participants is sufficient for phenomenological research, as it focuses on examining personal experiences from the participants' perspectives. The participants were chosen from among tenth-grade students who had participated in the teaching and learning of the SIA-DT module. Students were introduced to socio-scientific issues and tasked with designing and creating products that address user needs, following a structured process of Investigation, Ideation, Design, Invention, and Commercialization.

Data Collection

Individual semi-structured interviews were employed as the primary data collection method. This approach facilitates an in-depth exploration of participants' experiences, perceptions, and motivations, which might be challenging to capture through other methods (Creswell & Poth, 2018). Semi-structured interviews enable researchers to clarify and verify responses in real time, reducing misunderstandings and allowing participants to elaborate on their answers (Yin, 2018). The interviewer follows a set of prepared questions while maintaining flexibility to probe further based on the interviewee's responses. The interview questions were as follows:

1. How did the SIA-DT method help you develop and enhance your creative thinking skills when working on entrepreneurship projects?
2. What challenges do you face when implementing the SIA-DT integration method?

To validate the interview protocol, two qualitative study experts reviewed and evaluated it. A Content Validity Index CVI value of 1.00 indicates full expert agreement on all question items. A pilot interview involving three participants was conducted to refine the interview questions and identify potential issues. The researcher found that participants understood the questions well and provided appropriate answers. With the participants' consent, the researchers recorded the interviews and took comprehensive field notes during the study. Interview transcripts were shared with participants for accuracy verification. Two researchers independently coded and analyzed the data, comparing their findings to ensure consistency and reliability.

The interview with one participant lasted between 60 and 90 minutes. According to Guest et al. (2006), this duration is ideal for semi-structured interviews, as it effectively balances the need for in-depth responses with maintaining participant comfort. This duration allows for meaningful exploration of participants' experiences without overwhelming them. The research was conducted over a three-month period from May to July 2023.



Data Analysis

This study used thematic analysis to identify, analyze, and report patterns (or themes) emerging from qualitative data. The thematic analysis allows researchers to delve into the meanings embedded in interview content by focusing on main themes, sub-themes, and the relationships between them, requiring thoughtful reflection and interpretation (Braun & Clarke, 2006). Themes can be derived inductively, from the data itself (bottom-up), or deductively, based on theoretical frameworks (top-down) (Frith & Gleeson, 2004). This study employed an inductive approach, aligning the identified themes closely with the data. Through detailed analysis of interview content, the researcher explored recurring patterns in participants' experiences, aiming to explain these experiences within the study's framework (Fereday & Muir-Cochrane, 2006). The themes identified in this approach were directly related to the questions posed to participants, as outlined in the research questions.

Research Ethics

Permission to conduct the study was obtained from school principals, participants, and their parents. Participants were informed about the confidentiality measures maintained by the researcher. To protect their privacy, participants' identities were only accessible to the researcher. Informed consent meetings were held to explain the study's purpose, confidentiality, and anonymity measures. Participants were assured that their involvement was voluntary and that they could withdraw at any time. Consent forms from the participants were obtained at the conclusion of these meetings.

Research Results

Methods of the SIA-DT Approach in cultivating Creative Thinking in Entrepreneurship

Holistic Thinking by connecting scientific knowledge, societal challenges, and creative problem-solving

The SIA-DT learning method fosters holistic thinking by integrating science, society, and creativity. Through engagement with socio-scientific issues, Student 1 developed a comprehensive understanding of how these aspects are interconnected. Similarly, the design thinking process embedded in SIA-DT learning enabled Student 2 to apply creative thinking in developing meaningful solutions to societal challenges.

"...since learning about and following these socio-scientific issues, I feel more open and holistic in my perspective, especially on topics that intersect science and society. The design thinking process has also helped me express my creative ideas, especially in areas of social science and creativity." [M1/S1/22 Jun 2023/TTB_B:336-340]

"...socio-scientific issues and design thinking really broadened the horizons of my teammates and me. We not only learned about scientific facts but also how to apply creative thinking to develop meaningful solutions for socio-scientific issues facing society." [M2/S1/22 Jun 2023/TTB_B:328-333]

Exposure to socio-scientific issues and the design thinking process promotes holistic thinking, offering students a comprehensive and meaningful learning experience, as observed in Students 4, 6, and 7. Additionally, engaging with socio-scientific issues enhances students' ability to think creatively and develop solutions that benefit society. For instance, Student 9 gained new perspectives, enabling him to design products with meaningful societal contributions.

"Studying a module with socio-scientific issues and design thinking provided me with a meaningful experience. I learned to understand scientific and social issues, and I also learned how to think creatively to find solutions that have a positive impact on society." [M4/S2/22 June 2023/TTB_B:332- 337]

"The design thinking process has greatly enhanced my overall learning. It helps me understand socio-scientific issues and encourages creativity during product development, giving me a comprehensive sense of involvement while participating in the activities." [M6/S2/22 June 2023/TTB_B:327-332]



"The combination of socio-scientific issues and design thinking complements each other and has greatly supported my learning. I was able to apply my scientific knowledge to create innovative products and address social problems." [M7/S3/22 June 2023/TTB_B:342-347]

"Approaching socio-scientific issues through design thinking helps me and my peers view issues from multiple perspectives in design. This creative process enables us to design products that can truly contribute to society. It feels like the right time to create, and I believe I now understand scientific concepts more comprehensively." [M9/S3/22 June 2023/TTB_B:350-357]

Promoting Real-World Relevance, Critical Thinking, and Value-Based Reasoning through Socio-Scientific Issues

According to Student 9, the socio-scientific approach that was introduced reveals the realities present in students' environments. This is because the issues raised create opportunities for students to explore more deeply, making learning more relevant to social reality. Student 2 also noted that socio-scientific issues foster curiosity, leading to diverse perspectives among students and creating space for the development of critical thinking skills. Similarly, Student 7 explained that the socio-scientific issues discussed encouraged thinking in terms of values and social impact.

"...from what I see, this socio-scientific issue feels more relevant because it revolves around real-world issues in our community. We discuss situations that are actually happening around us, not just hypothetical ones. There's so much knowledge to gain here, and much of it can be applied in everyday life." [M9/S3/22 Jun 2023/TTB_B:57-61]

"...I found that these issues have various points of view, so when we encounter complex issues, we try to evaluate and think critically to address them. I think, even though it's challenging, our interest increases because we think deeply and find effective solutions." [M2/S1/22 Jun 2023/TTB_B:62-66]

"...well, teacher, what's most clear to me is that this socio-scientific issue leads us to think about values and social implications. Besides the many facts we gain from these issues, we also evaluate the impact of values, and the social decisions made. It feels like learning becomes more meaningful because it's not just about knowing to be smart." [M7/S3/22 Jun 2023/TTB_B:72-77]

Transformative Learning through Socio-Scientific Engagement

The findings from the interview with Student 6 indicated that learning through the SIA-DT module provided a new experience that altered students' perceptions of social reality. This approach offers students a more engaging and relevant learning experience, as they can apply knowledge in real-life contexts. By discussing socio-scientific issues, students explore the social impact of these issues and seek solutions that can benefit society.

"...it's time to do this module activity! I can never wait to start because it's always something new. This SIA-DT method has really opened my eyes. These modules focus a lot on real issues, so I think the experience feels more authentic and relevant to us. I also get to think with my group members about the social impact of these issues and explore ways to address and help the community." [M6/S2/22 Jun 2023/TTB_B:84-90]

Student 1 also supports Student 6's statement that the SIA-DT method allows students to apply creative ideas through new experiences, emphasizing that this approach goes beyond learning theory and facts alone. It enables the development of practical skills for creating something useful. Additionally, Student 2 expressed excitement about designing new products, noting the positive impact their creations can have on the surrounding community.

"...the design thinking process in this module gave me a new experience. Before this, I had never heard of this type of design thinking. Here, I can use my creative ideas—usually, in studying this science, I just



remember the facts. But this time, I was able to apply my skills to create a useful product, so we could experience the process of bringing those ideas to life.” [M1/S1/22 Jun 2023/TTB_B:91-98]

“...in this module, we design a new product. We work together to create a product that meets the needs of the community. We don’t just focus on design; it’s important to ensure that our products are developed to have a positive impact on the community.” [M2/S1/22 Jun 2023/TTB_B:87-92]

Student 8 and Student 6 both expressed joy from the new experiences they gained through the SIA-DT module. This module, which focuses on socio-scientific issues, provides Student 8 the opportunity to explore various perspectives, while Student 6 feels a sense of fulfillment as a creator through this experience.

“...the socio-scientific issues in this module allow us to receive various opinions. This is a new experience. These issues help us think about higher-order thinking skills (HOTS) and understand the difficulties that society is facing. During discussions about socio-scientific issues, I learn from the perspectives of different group members. I can listen to different opinions, be tolerant, and learn to communicate my ideas effectively.” [M8/S3/22 Jun 2023/TTB_B:97-104]

“...this is the first time I am participating in a product creation activity that uses issues and design thinking. Although this is new to me, I think it’s really fun. The steps of design thinking in the module have a clear structure, which makes it easy for us to design a product. I can feel what it’s like to be a designer. This is not just learning; it’s a creative process of experience. We don’t just think about the final product but go through the creative process.” [M6/S2/22 Jun 2023/TTB_B:103-104]

Fostering Systematic Inquiry and Creative Problem Solving through Socio-Scientific Issues.

Almost all students stated that the SIA-DT method helps them conduct investigations systematically and in an orderly manner. As Student 3 noted, socioscientific issues add a dimension of in-depth understanding to the topics surrounding students.

“...in the issue presented in the module, we can understand the real context. For example, in the face mask-making activity, there is an issue indicating that fabric masks are better than disposable ones. This is when I understood that not all masks are the same.” [M3/S1/22 Jun 2023/TTB_B:15-20]

The above statement is also supported by Student 1 and Student 8, who noted that the socio-scientific issues discussed helped them understand the real-world context of the products they created, as they had to study relevant social issues directly while seeking innovative solutions. This process not only develops critical skills in analyzing problems but also fosters creativity in product development.

“...In the module, there is one issue that caught my attention, which is about wet tissues for babies. Before this, I always thought wet tissues were clean and could kill viruses. However, in this issue, I found information that provided very important insights. Apparently, baby wipes are only antibacterial and don’t kill viruses. This made me realize how important accurate information is for understanding the real context of the products we use, ensuring that the products we create are more relevant to the issues at hand.” [M1/S1/22 Jun 2023/TTB_B:23-26]

“...while learning to use the module, we often combine socio-scientific issues in the production of hand sanitizing products. We need to ensure that the alcohol content is between 60% and 80%. I found that my friends and I sought innovative solutions, not just to create a good product but also to address the issue at hand.” [M8/S3/22 Jun 2023/TTB_B:19-25]

Enhancing Evaluation and Decision-Making Skills through Socio-Scientific Issues



The SIA-DT approach to socio-scientific issues empowers students' assessment skills, enabling them to assess selected ideas based on their potential to address the identified socio-scientific challenges. At the same time, Student 1 and Student 3 noted that the SIA-DT learning method offers students a unique opportunity to engage with socio-scientific issues they may not be familiar with, as well as to assess ideas by providing relevant arguments. This process helps to develop essential assessment skills necessary for addressing socio-scientific issues.

"What do I think? This SIA-DT experience gives us the opportunity to address socio-scientific issues that occur, even those we might not usually notice. I learned to evaluate ideas and provide suitable arguments to solve these socio-scientific issues." [M1/S1/22 Jun 2023/TTB_B:235-239]

"By working with socio-scientific issues in SIA-DT, I was trained to examine the relationship between science and societal issues more deeply. This has helped me evaluate selected ideas more critically. I now better understand how a good idea should positively impact the resolution of existing socio-scientific issues." [M3/S1/22 Jun 2023/TTB_B:253-258]

For Student 5, the socio-scientific issues highlighted in the SIA-DT module provide a real context for investigating societal problems, guiding students to become more sensitive to the need for effective solutions. Student 7 noted that the approach to socio-scientific issues in SIA-DT strengthened his evaluation skills, which directly aided him in selecting the best idea for designing a new product. Supporting the statements of Students 5 and 7, Student 9 indicated that through SIA-DT, he learned to evaluate ideas by assessing the effectiveness of the proposed design in addressing the identified socio-scientific issue.

"The socio-scientific issues in SIA-DT provide a realistic overview of societal problems. Through this initial investigation, we are trained to make decisions and evaluate ideas, helping us become more sensitive to effective solutions." [M5/S2/22 Jun 2023/TTB_B:248-252]

"I find that the socio-scientific issues in SIA-DT have greatly helped improve my evaluation skills. By evaluating carefully, I can choose the best ideas—those that can have a positive impact on society." [M7/S2/22 Jun 2023/TTB_B:239-243]

"In SIA-DT, we also learned to make informed decisions, especially when creating product sketches. I learned to evaluate ideas by assessing how well the design sketches address the socio-scientific issues we discussed. This process builds our skills in evaluating and aiming to solve these issues." [M9/S3/22 Jun 2023/TTB_B:247-253]

Fostering Creative Thinking and Innovation through Socio-Scientific Discussions supported by Stimulus Images

The findings from the interviews with Student 3 and Student 9 indicate that the SIA-DT method encourages students to engage more maturely in discussions about the socio-scientific issues presented, leading to the development of innovative and creative skills among them. Similarly, Student 2 noted that the approach to socio-scientific issues and design thinking fosters the creation of innovative products aimed at addressing these issues, helping both Student 2 and Student 6 understand the importance of scientific knowledge in product innovation. Additionally, Student 7 stated that the SIA-DT learning method enhances critical thinking skills during the idea generation process.

"During the new idea stage, our group discusses and identifies similarities within the social and scientific aspects of the given socio-scientific issue. As a result, by truly understanding the socio-scientific issue, we don't just create—we approach product development with greater maturity." [M3/S1/22 Jun 2023/TTB_B:286-291]

"SIA-DT taught me to approach discussions about socio-scientific issues with greater maturity. During my learning, I was able to foster more innovative and creative product ideas. The scientific knowledge gained through debating these issues became a key contributor to this creative process."

[M9/S3/22 Jun 2023/TTB_B:291-296]

"SIA-DT really opened my eyes to the importance of scientific knowledge in creating innovative products. For example, during discussions and debates about socio-scientific issues, I learned to combine scientific



knowledge with social considerations to produce creative and beneficial ideas for society.” [M2/S1/22 Jun 2023/TTB_B:271-276]

The stimulus images shown in the SIA-DT module provide an added dimension of visualization, helping students improve their understanding of concepts, as stated by Student 3 and Student 6. Additionally, Student 6 noted that the stimulus images increase their engagement and interest, a point supported by Student 8, who described the stimulus images as materials that catalyze students’ thinking skills—not only during the investigation step but also as a trigger for new ideas.

“Stimulus pictures greatly help us understand what needs to be produced. Previously, the concepts were abstract, but with stimulus pictures, the ideas become clearer compared to just reading the text.” [M3/S1/22 Jun 2023/TTB_B:46-49]

“Thankfully, there are stimulus pictures that pique my interest and encourage greater participation in learning. When pictures are included, there is more enthusiasm, making the experience more active and fun. As a result, I feel very involved in the production of new products.” [M6/S2/22 Jun 2023/TTB_B:41-49]

“...I think... hmm... the stimulus pictures also help in generating new ideas. They prompt us to consider what features our product might be missing compared to products currently on the market.” [M8/S3/22 Jun 2023/TTB_B:47-50]

Product Development through the Structured SIA-DT Module and Teamwork

Based on the interview findings, Student 5 and Student 7 stated that the SIA-DT module helped them plan product development and visualize each step and design concept in an orderly manner. Similarly, Student 6 noted that the systematic structure of the SIA-DT module serves as a step-by-step guide in product development.

“...in this module, there are steps that I find very helpful in the process of producing a product. I can plan and visualize each step in a more organized manner. For example, when we design our product prototype, we generate ideas by considering aspects such as the function and use of the product.” [M5/S2/22 Jun 2023/TTB_B:25-31]

“...one advantage that I clearly see in using this module is the ability to visualize the design effectively. I can see how each element of the product relates to and interacts with one another. This visualization has helped me significantly in understanding every aspect of the project before moving on to the implementation step.” [M7/S3/22 Jun 2023/TTB_B:29-36]

“...in learning to use this module, I find it very helpful because it provides a structured approach that is systematic and orderly in the design process. This model appears to be a step-by-step guide, starting from the conceptualization of the idea to the execution of the project. With this structure in place, I can be more consistently involved, ensuring that each step is carried out clearly and effectively. This gives me great confidence and makes the design process more manageable.” [M6/S2/22 Jun 2023/TTB_B:23-32]

Sharing the same opinion, Student 9 stated that the use of the design thinking model in the SIA-DT Module stimulates student creativity by allowing them to create and explore ideas more freely. Similarly, Student 2 added that the design thinking model in this module also fosters collaboration between groups, as effective communication takes place, which, as Student 3 noted, speeds up the product development process.

“...I think this module really stimulates my creativity. It allows us to create and explore ideas more freely and to try unique and innovative concepts. This way, we can produce products that effectively meet the needs of our audience.” [M9/S3/22 Jun 2023/TTB_B:32-36]

“...in group work, we were able to express our opinions clearly about what to create. The module was very helpful in understanding the concept and collaborating effectively to produce the desired design. We were



also able to communicate more effectively, which improved our teamwork in achieving our design goals.”
[M2/S1/22 Jun 2023/TTB_B:40-45]

Enhancing Decision-Making and Product Value Assessment

The results of the interviews with Student 3, Student 1, and Student 4 painted a very positive picture of the impact of learning through the SIA-DT method on students’ decision-making skills. Similarly, Student 6 and Student 5 noted that the design thinking process within the SIA-DT framework helps students identify important features for the products they create. The effect of the SIA-DT method also empowers decision-making skills related to determining product value. This aligns with Student 8’s statement that in SIA-DT learning, setting product prices involves more than just financial decisions; it focuses on developing students’ decision-making skills by emphasizing product value. This ensures that the prices set are not only competitive but also beneficial to society. Additionally, through the interviews, the researcher found that the SIA-DT learning method assists Student 9 in making informed decisions regarding the choice of marketing medium.

“...SIA-DT really helped me and my group members make decisions, especially when choosing the product design. After all, I noticed that socio-scientific issues are very helpful in making important decisions to ensure that the product has a positive impact on society.”
[M3/S1/22 Jun 2023/TTB_B:194-199]

“...I think the design thinking process provides clear guidance that helps in making decisions, which supports the creation of creative and innovative prototypes.”
[M1/S1/22 Jun 2023/TTB_B:203-205]

“...in SIA-DT, we’re not only focused on producing creative products; we also need to consider decisions that impact socio-scientific issues. For example, even when naming a product, it’s important to make a thoughtful decision, as the product’s name reflects the values and goals we want to convey. I think this experience has really strengthened my decision-making skills.”
[M4/S2/22 Jun 2023/TTB_B:196-202]

Structured Product Development through Creative Design and Planned Implementation

Student 1 explained in an interview that during the design phase, they were given the opportunity to formulate new ideas through sketches. The steps outlined in the SIA-DT module are very helpful for students to conduct an initial assessment of their ideas’ feasibility before implementation. Student 4 shared a similar opinion, noting that the SIA-DT method’s focus on the design phase aids students in generating new ideas through sketches. This process ensures that students implement only those ideas that can truly become a reality and have a positive impact. Student 6 also acknowledged that the design process in SIA-DT guarantees that every idea or product developed during this phase is well planned.

“...in the design phase, we are given the opportunity to create new ideas through sketches, allowing us to make a preliminary assessment of the idea’s feasibility before implementation. This process ensures that our ideas are practical and have a positive impact.”
[M1/S1/22 Jun 2023/TTB_B:272-276]

“...the best thing about SIA-DT is that we can sketch new ideas during the design phase. This allows us to evaluate the feasibility of each idea and ensure that the chosen one is effective. We become more critical when selecting the best idea.” [M4/S2/22 Jun 2023/TTB_B:296-302]

“...the design process in SIA-DT ensures that every product created in the design phase is well planned. During prototype production, we can review and adjust every aspect of the product’s functionality and effectiveness before it goes to market.” [M6/S2/22 Jun 2023/TTB_B:313-317]

Student 5 revealed that the creation phase in SIA-DT makes the production process of prototype products more planned. The creation phase in SIA-DT teaches Student 5 to implement ideas or produce new products that



have been formulated and also teaches students to create products in a planned manner, as explained by Student 8 and Student 9.

"...the create phase in SIA-DT taught me to implement the selected idea.. by implementing the idea a little first... we can test its functionality and effectiveness... this allows us to test our product first before introducing it to the market widely..." [M5/S2/22 Jun 2023/TTB_B:299-305]

"The design and creation phase in SIA-DT leads to the planned creation of a product. We learn to formulate ideas, evaluate their feasibility, and implement them carefully. This process promotes the effectiveness and positive effects of the products produced..." [M8/S3/22 Jun 2023/TTB_B:313-317]

"...SIA-DT provides a planned approach in product creation. The design phase gives us the platform to creatively formulate ideas, while the create phase allows us to test and perfect the product before making a big impact in the market..." [M9/S3/22 Jun 2023/TTB_B:322-327]

Integrating Societal Impact and Commercial Viability in Entrepreneurial Design

The integration of socio-scientific issues and design thinking in the SIA-DT Module encourages students to critically assess the practicality of the products developed. As a result, students analyze the expressed socio-scientific issues and consider the process of creating products with commercial value to ensure market acceptance. Student 3 noted that the SIA-DT Module places significant emphasis on relevant socio-scientific issues, which helps students understand how their products can positively impact society.

"...I see that the SIA-DT module focuses on relevant socio-scientific issues, helping us understand how the products we create can impact the community. When we discuss the commercial phase, we also consider the product's usability to ensure it fulfills actual user needs." [M3/S1/22 Jun 2023/TTB_B:363-368]

Learning the SIA-DT module opens up opportunities to integrate social values and community needs at each phase of entrepreneurial creative thinking. Student 1 echoed the sentiments of Student 3, noting that in discussing the commercial value of a product, they also considered its practicality, functionality, and overall impact on society. For Student 5, the SIA-DT Module encourages students to think about the usability of the product. The socio-scientific issue analysis process also helps Student 6 gain a deeper understanding of the social impact of a product. Student 6 further stated that by understanding an issue, they feel more open to considering societal values in product design. This aligns with Student 7's opinion, who mentioned that through the SIA-DT Module, they can evaluate the commercial aspects of product production while also understanding market trends and consumer needs, leading to the design of quality products that are appealing in a competitive market.

"...I like the SIA-DT module; it taught me and my group members to think carefully about the product's usability. This way, the product will be easier to market and reach the intended audience. We need to create a product that is user-friendly." [M5/S2/22 Jun 2023/TTB_B:367-371]

"...what can I say... while analyzing the socio-scientific issue, I gained a deeper understanding of the social impact of each product. I also became more open to considering societal values in product design, so the products we create can meet consumer needs and contribute to social well-being." [M6/S2/22 Jun 2023/TTB_B:381-387]

"...I think it's important to consider the commercial aspect of product production. This SIA-DT module opened my eyes to the need to satisfy the market to achieve commercial success. After all, I discovered that if we understand market trends and consumer needs, we can produce quality products that stand out in this highly competitive market." [M7/S3/22 Jun 2023/TTB_B:396-403]

In addition, the SIA-DT Module is highly beneficial for students in making informed judgments about material usage and product usability. As a result, students are able to apply ethical values throughout the product production process. In learning the SIA-DT Module, Student 8 noted that their group emphasized sustainability by choosing environmentally friendly materials to ensure that the products produced benefit both consumers and the environment.



"...I found that with the SIA-DT module, my group members and I can make detailed judgments about the materials used and the principles behind the products we create. When selecting materials for the product, we emphasize ethics and sustainability, using environmentally friendly materials to ensure safety for both the community and the environment." [M8/S3/22 Jun 2023/TTB_B:383-389]

Creativity and Innovation in Product Marketing

Student 2 expressed his view that the SIA-DT Module provides an accurate and relevant focus on various product marketing strategies, including digital marketing. Student 3 shared a similar perspective, noting that the SIA-DT Module helps students become more creative in the context of product marketing.

Student 2's opinion is supported by Student 4, who stated that their creativity skills have also improved through learning the SIA-DT Module. Through the activities and guidance provided, Student 4 has experienced an increase in their ability to make products stand out in the market. Creativity in product production is evident not only in the design and functionality of each product but also in the creation of sustainable products. This sentiment was echoed by Students 8 and 9, who noted that they are now more aware of the impact of products on the environment and society.

"...this SIA-DT module provides a strong focus on product marketing. We were guided to explore the world of digital marketing through TikTok, Facebook, and Instagram. While these apps are primarily social media platforms, in this module, we learn to use them for marketing products. We are also guided on how to effectively introduce innovative products. This experience has truly opened my eyes to the different types of marketing strategies." [M2/S1/22 Jun 2023/TTB_B:403-409]

"...I think this SIA-DT module is very helpful in guiding students to be more creative in product marketing. They previously only used picture ads. The activities in the module greatly assist in understanding how to make products more accepted in the market. By focusing on creative commercial activities, we can attract the public's attention to the product more effectively." [M3/S1/22 Jun 2023/TTB_B:399-405]

"...I believe our creativity has significantly increased after following the SIA-DT method. Through the guidance and activities provided, I feel that I can now see how to make the product stand out and be noticed in the market." [M4/S2/22 Jun 2023/TTB_B:418-422]

The Challenges of Implementing the SIA-DT Method in Cultivating Creative Thinking in Entrepreneurship

Challenges in Developing Creative and Critical Thinking Through Contextual Understanding in Socio-Scientific Product Development

The findings from the interviews indicated that exposure to various scientific and social issues provoked differing opinions in the effort to generate new ideas. However, this exposure also posed challenges in developing critical and creative thinking skills among students. In an interview with Student 3, he agreed that one of the main challenges in implementing the SIA-DT module is the difficulty of thinking creatively and generating new ideas, as producing innovative concepts requires a solid foundation of existing knowledge. This point is also supported by Student 7, who stated that in product development, students need the ability to compare, analyze, evaluate, and make decisions about the ideas that emerge. Similarly, Student 8 noted the necessity of being able to compare and analyze various ideas, evaluate their strengths and weaknesses, and choose the most effective option.

"...I think the main challenge in this module is to create new ideas. This means that to produce creative and innovative concepts, we need to think of products that can solve the discussed issues and meet user needs. For this, we require a lot of information and knowledge, so having prior knowledge is essential." [M3/S1/22 Jun 2023/TTB_B:125-131]

"...I think the most challenging aspect is the time constraint. During the discussion of new ideas, we need to make comparisons, conduct analyses, evaluate options, and choose which one



to develop. We aim to select the idea that is most effective in solving socio-scientific issues.”
[M7/S3/22 Jun 2023/TTB_B:122-126]

The findings from the interviews revealed that students participating in the SIA-DT module faced the challenge of producing products that solve socio-scientific issues. Student 1 and Student 2 emphasized the importance of having a deep understanding and knowledge of the context of the issue to create effective solutions. Meanwhile, Student 5 and Student 6 highlighted the active role students must take in thoroughly exploring and studying the given issue as a significant challenge in product development.

“...I think one of the important challenges we face is figuring out how to produce a product that can genuinely solve the socio-scientific issues discussed. We don’t just want to create a product; we also need to understand the issue in depth to develop the best solution. What I learned is that having a strong understanding and knowledge of the issue’s context is essential. Therefore, our group discussion time must be really focused.”
[M1/S1/22 Jun 2023/TTB_B:148-156]

“...in creating the right product, we can’t just focus on the design; we must truly understand the socio-scientific issues involved. For example, when producing face masks, we also need to consider the issue of face mask disposal, which can lead to environmental pollution. By understanding these issues, we can develop products that genuinely have a positive impact on the environment.”
[M2/S1/22 Jun 2023/TTB_B:163-169]

Table 1 displays a summary of qualitative findings.

Table 1
Summary of Qualitative Findings

<i>Methods of the SIA-DT Approach in cultivating Creative Thinking in Entrepreneurship</i>	
	Theme
1	Holistic thinking by connecting scientific knowledge, societal challenges, and creative problem-solving
2	Promoting real-world relevance, critical thinking, and value-based reasoning through socio-scientific issues
3	Transformative learning through socio-scientific engagement
4	Fostering systematic inquiry and creative problem solving through socio-scientific issues.
5	Enhancing evaluation and decision-making skills through socio-scientific issues
6	Fostering creative thinking and innovation through socio-scientific discussions supported by Stimulus Images
7	Product Development through the Structured SIA-DT Module and Teamwork
8	Enhancing decision-making and product value assessment
9	Structured Product Development through Creative Design and Planned Implementation
10	Integrating societal impact and commercial viability in entrepreneurial design
11	Creativity and innovation in product marketing
<i>The Challenges of Implementing the SIA-DT Method in Cultivating Creative Thinking in Entrepreneurship.</i>	
	Theme
1	Challenges in developing creative and critical thinking through contextual understanding in socio-scientific product development



Discussion

The findings of this study highlight how the integration of the SIA-DT method fosters students' creative thinking in entrepreneurship (CTE). Overall, students responded positively to the implementation of this method, encountering only a few challenges during the process.

Integrating socio-scientific issues with the design thinking process fosters holistic thinking by connecting scientific knowledge, societal challenges, and creative problem-solving. Research indicates that socio-scientific inquiry encourages students to explore complex relationships between scientific knowledge and societal needs, promoting a comprehensive understanding of real-world challenges (Sadler, 2011). Through this process, students develop a well-rounded perspective that integrates scientific reasoning with social considerations. These results are consistent with the findings of Shadiev et al. (2022), which demonstrate that cultivating students' understanding of diverse social contexts and real-world challenges enhances their ability to approach entrepreneurship with greater creativity and innovation.

Additionally, integrating socio-scientific issues into science learning supports perspective-taking and ethical reasoning, enabling students to approach problems from diverse viewpoints. This approach aligns with socio-scientific issue-based learning, which emphasizes real-world applications to cultivate critical thinking, creativity, and social responsibility (Zeidler & Sadler, 2008). By grappling with authentic societal challenges, students learn to evaluate multiple perspectives, balance conflicting interests, and make informed decisions. Research by Sadler (2011a) underscores similar benefits, demonstrating that engaging with socio-scientific issues enhances students' critical thinking by connecting classroom learning to real-world contexts. While prior research focused on critical thinking, the research findings also highlight the role of value-based reasoning, as noted by Student 7. Successful entrepreneurs consider social impact and ethical implications, similar to value-based reasoning promoted through socio-scientific discussions. This aligns business goals with societal needs, creating socially responsible entrepreneurs.

This study suggests that when students investigate real-life problems, they not only apply academic knowledge but also develop essential skills such as critical thinking, problem-solving, and ethical reasoning. The development of these competencies prepares students to analyze complex entrepreneurial challenges, evaluate risks, and devise strategic solutions. By connecting science learning with societal issues, socio-scientific inquiry empowers students to generate innovative ideas and cultivate entrepreneurial thinking.

Additionally, engaging students with real-world issues through the SIA-DT approach to socio-scientific issues enhances their evaluation and decision-making skills. This aligns with Zeidler and Keefer's (2003) findings, which highlight that exposure to socio-scientific issues fosters argumentation and evaluative reasoning. Students learn to assess evidence, consider diverse perspectives, and justify their decisions through well-reasoned arguments—essential skills for entrepreneurial creativity. Creative thinking in entrepreneurship involves generating innovative ideas, evaluating their feasibility, and developing solutions to meet market needs. The SIA-DT approach mirrors this process by encouraging students to evaluate multiple solutions for complex socio-scientific problems. Through structured evaluation and argumentation, students enhance their ability to identify opportunities, weigh alternatives, and design viable products—core aspects of creative thinking in entrepreneurship.

Contrary to these findings, Sadler (2011b) contended that the complexity of socio-scientific issues can overwhelm students, ultimately hindering learning outcomes. While some researchers argue that socio-scientific approaches may be too demanding for younger learners, this study suggests that guided socio-scientific discussions can alleviate these challenges. By engaging with socio-scientific issues through such discussions, students not only enhance their understanding of the topics but also develop essential entrepreneurial skills, including innovation, creative problem-solving, and the practical application of knowledge. These findings underscore the value of integrating the SIA-DT method, which helps bridge the gap between theoretical knowledge and real-world applications, fostering both creative problem-solving and entrepreneurial thinking.

This study highlights how the SIA-DT module facilitates transformative learning by enabling students to undergo meaningful shifts in their perspectives, beliefs, and understanding through socio-scientific learning approaches. By examining real-world socio-scientific issues, students engage in purposeful and relevant learning experiences. This process fosters creativity as they brainstorm innovative solutions with tangible societal impact. The module encourages students to connect theoretical knowledge with practical applications, think critically, and develop viable solutions to complex challenges. These aspects collectively demonstrate how the SIA-DT module nurtures students' creative thinking and entrepreneurial mindset by transforming abstract concepts into real-life



innovations. These findings align with Mezirow's (1991) Transformative Learning Theory, which emphasizes how meaningful experiences can reshape learners' perspectives, fostering critical thinking and personal development.

The design thinking process embedded in SIA-DT learning enables students to apply creative thinking in developing meaningful solutions to societal challenges. Design thinking is recognized for enhancing problem-solving skills through processes such as empathy, ideation, and iterative prototyping (Brown, 2009; Razzouk & Shute, 2012). SIA-DT learning encourages students to think critically about societal issues, which in turn nurtures creativity in seeking innovative solutions (Gok et al., 2020). The use of stimulus images in the SIA-DT module enhances visualization and conceptual understanding, key aspects of entrepreneurial creativity. Entrepreneurs often rely on visual prompts, prototypes, and conceptual models to explore possibilities and develop innovative solutions. This mirrors how stimulus images in the SIA-DT framework trigger students' thinking, enabling them to connect concepts, identify opportunities, and design creative solutions. Gero (1990)'s work on design thinking highlights how visual representations (such as sketches and diagrams) play a central role in the creative process, enabling individuals to conceptualize, explore possibilities, and innovate. This mirrors the use of stimulus images in the SIA-DT approach to trigger students' creative thinking.

The structure of the design thinking model, as outlined in the SIA-DT module, fosters creativity in entrepreneurship by offering a step-by-step guide that helps students plan, visualize, and implement product development. This systematic approach helps students break down complex challenges into manageable steps, enabling them to generate and develop innovative solutions. As Brown (2009) explains, the structured process of design thinking facilitates creativity by allowing entrepreneurs to explore multiple solutions, prototype rapidly, and refine ideas based on feedback. This approach is crucial in entrepreneurship, where creative thinking is essential for identifying market opportunities and designing effective products.

The SIA-DT framework enhances students' decision-making skills, particularly in evaluating product features, determining product value, setting prices, and selecting marketing strategies. Through engaging with the design thinking process, students are encouraged to make informed, value-driven decisions that consider both financial considerations and the broader societal impacts of their choices. This holistic approach to decision-making is crucial in entrepreneurship, where the ability to balance economic and social factors is key to success. Brown (2009) highlights the importance of assessing product value and making thoughtful pricing decisions, a concept that aligns with the SIA-DT framework's focus on product development. Similarly, Kimbell (2011) and Martin (2009) emphasize how design thinking fosters well-rounded decision-making by prompting individuals to consider both the tangible and intangible aspects of products and services. This integration of financial and social value makes students more adept at making strategic decisions that are not only profitable but also beneficial to society.

The SIA-DT framework promotes creative thinking in entrepreneurship by guiding students through structured phases of design and creation, facilitating the generation and refinement of ideas. This approach nurtures entrepreneurial creativity by encouraging the development of practical, well-conceived products. It aligns with the research by Liao and Welsch (2005), which suggests that integrating structured learning environments with entrepreneurial training enhances creative skills, enabling students to generate innovative business ideas and identify novel solutions to community challenges.

The findings highlight how the SIA-DT module nurtures entrepreneurial creative thinking by guiding students to balance societal impact and commercial viability. By incorporating socio-scientific issues into product design and development, students consider the usability, functionality, and social value of their products, which are crucial for entrepreneurial success. This approach fosters innovative thinking as students explore market trends, consumer needs, and social responsibility—critical components for developing products that are both creatively impactful and commercially viable, as supported by Brown (2009), Kimbell (2011), and Martin (2009).

The SIA-DT module fosters creativity not only in product design but also in marketing strategies. By promoting innovative thinking in both product development and digital marketing, students are equipped to create products that are functional, visually appealing, and stand out in the competitive marketplace. Additionally, the module helps students align their entrepreneurial efforts with societal impact, a key factor for long-term business success (Brown, 2009).

While the SIA-DT method offers significant advantages for fostering students' creative thinking in entrepreneurship (CTE), students face challenges in effectively implementing this integrated approach. The SIA-DT method underscores the interdependence of critical and creative thinking skills alongside contextual knowledge, emphasizing that developing innovative solutions to socio-scientific issues requires not only strong analytical and evaluative skills but also a deep understanding of the context in which these problems arise. Kolb's (1984) Experiential Learning Theory further highlights the importance of context and experience in the learning process, including



the development of entrepreneurial creativity. For entrepreneurs, a strong grasp of market trends, customer needs, and industry context is essential. Without sufficient background knowledge, students may struggle to identify problems worth solving or create marketable products. As Drucker (1985) emphasized, innovation is driven by a deep understanding of market dynamics, customer needs, and industry-specific trends. Entrepreneurs who lack this specific contextual knowledge are less likely to identify viable product opportunities. Therefore, Kolb's (1984) Experiential Learning Theory should be incorporated into the proposed SIA-DT integration model to maximize its impact.

Conclusions and Recommendations

This research highlights the pivotal role of the SIA-DT integration method on fostering students' creative thinking in entrepreneurship. The SIA-DT approach empowers students to think creatively while remaining socially and scientifically informed. By nurturing holistic thinking, critical thinking, transformative learning, systematic inquiry, value-based reasoning and creative problem solving, it paves the way for innovative and socially responsible entrepreneurship. The SIA-DT approach has the potential to cultivate well-rounded entrepreneurs by integrating creativity, critical thinking, and strategic planning and marketing. By developing assessment and decision-making skills, collaboration abilities, strategic planning, and market-driven innovation, students are equipped to create products that are both impactful and commercially viable. Although challenges remain in certain areas, the SIA-DT integration model holds significant potential to shape the next generation of creative entrepreneurs, particularly with the inclusion of Kolb's Experiential Learning Theory in its implementation.

Future research could explore how the SIA-DT method impacts students' creative thinking in entrepreneurship over time. Tracking students who have used this approach in their learning could provide insight into its effectiveness in real-world entrepreneurial success. Additional research could focus on how collaboration with students from different disciplines (e.g., engineering, business, social sciences) within the SIA-DT framework influences the development of innovative products. This could highlight the impact of diverse perspectives on creative thinking in entrepreneurship. Bottom of Form

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Declaration of Interest

The authors declare no competing interest.

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