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INTEGRATION OF SOCIOSCIENTIFIC APPROACH AND DESIGN THINKING: AN ENTREPRENEURIAL CREATIVE THINKING MODULE FOR STEM EDUCATION

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Abstract. *This study was conducted to i) ascertain the validity, reliability, and feasibility of a module based on the socioscientific issue approach and design thinking model (SIA-DT), and ii) assess its effects on the entrepreneurial creative thinking (ECT) in STEM education. The first phase of ECT module validation was conducted with the assistance of three expert evaluators and 32 students. A 5-point Likert scale questionnaire and the ECT test were used to collect data. The second phase consists of evaluation using a quasi-experimental design with a Pre-Post Test of Non-Equivalent Control Groups. A total of 64 Form Four students were divided into two groups: SIA-DT (n = 32) and control (n = 32). The ECT module has a high validity value and an acceptable Cronbach's alpha reliability of .92. The ECT Module's feasibility was substantiated by a mean score of 4.71. The results of the independent-sample t-test prove that there is a significant difference in the post-test for students in the SIA-DT group compared to the control group in ECT and five constructs of ECT. In conclusion, these findings demonstrate that the ECT Module is valid, reliable, and feasible in STEM education and that it is effective in enhancing students' ECT.*

Keywords: *design thinking model, entrepreneurial creative thinking, module development, socioscientific issue approach, STEM education*

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Introduction

The application of entrepreneurial thinking in teaching and learning can produce potential entrepreneurs capable of innovating new ideas or products by leveraging existing opportunities. According to Bacigalupo et al., (2016), implementing entrepreneurial thinking in students through training and experiences in school will result in students who can think like entrepreneurs identifying opportunities in the market and exploring suitable ways to capitalize on them. A student with an entrepreneurial mindset will always be innovative in solving problems (Nadelson et al., 2018).

Therefore, a learning model that nurtures entrepreneurial thinking in teaching and learning at schools needs to be introduced. Based on this need, Buang et al. (2009) aimed to understand the entrepreneurial scientist's thinking that led to innovative science-based products. Their qualitative findings indicated that respondents integrated entrepreneurial thinking and scientific process skills in producing innovative science-based products. As a result, they proposed the Science Entrepreneurial Thinking (SET) learning model that can be used as a teaching model in the science curriculum at the primary and secondary school levels. Based on integrating science and entrepreneurship disciplines, the SET learning model consists of five steps: observation, new ideas, innovation, creativity, and value. However, the SET learning outcomes conclude with students gathering community perspectives on product ideas through surveys. Subsequently, the analysis of these surveys is presented to their peers in the classroom. The students are not guided through the steps to introduce their product ideas to the market.

New ideas or products may not necessarily guarantee their ability to penetrate the market, especially in a rapidly changing technological and market environment. These products might be introduced too early or too different to be accepted in the market (Perry-Smith & Coff, 2011). Fresh ideas or products might hold value, yet their true worth is determined by their reception in the market (Della Corte & Del Gaudio, 2017). Therefore, in the endeavour to innovate ideas or products, creativity can elevate an idea or product to have value in the market (Shepherd & Patzelt, 2011). Creativity in the entrepreneurial context not only emphasizes extraordinary or unique

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products, but it should also have the capability to penetrate the market and generate profits (Perry-Smith & Coff, 2011).

It is clear here that the element of creativity in entrepreneurship can be highlighted as the creative thinking of entrepreneurs in creating products and marketing them creatively to generate profits. Therefore, the application of entrepreneurial creative thinking should equip students with fundamental skills and knowledge to innovate and market ideas or products, subsequently generating income in a dynamic technological and market environment.

Kennedy and Odell (2014) noted that STEM education applies the process of designing solutions to complex contextual problems using current tools and technologies (p. 246). Entrepreneurial creative thinking opens up space for students to think more broadly to explore new ideas in STEM-based problems. Owens et al. (2017) stated that the socioscientific issue approach helps students to develop and evaluate arguments related to current issues and connect them to the interests of society. Therefore, there is a need in fostering entrepreneurial creative thinking in STEM education to increase students' awareness of current issues in the society and encourage them to think outside the box in finding solutions to problems through the design process.

According to Jacobson et al. (2006), a teaching and learning module as a training package helps students understand or master skills or learning units effectively. Hence this research was carried out to determine whether the ECT teaching and learning module developed as a result of the integration of socio-scientific approach and design thinking in STEM education can develop ECT of students. The necessity of this study also aligns with the requirements of the Malaysian Education Development Plan 2013-2025, which encourages the incorporation of Entrepreneurship Cross-Curricular Elements into teaching and learning (Ministry of Education Malaysia, 2012).

Theoretical Framework

The design and development of the ECT teaching and learning module based on the socio-scientific approach and design thinking model are executed through the analysis of various elements, such as the socio-scientific approach, design thinking model, implementation of STEM education in schools, understanding of students' learning styles in secondary school, and their correlation with theories and learning models. As the produced module is focused on Form Four students in secondary school, it applies both Piaget's Cognitive Constructivism Theory (Piaget, 1976) and Social Constructivism Theory (Vygotsky, 1978).

In line with the research subject, which involves Form Four students, the constructivism theory is appropriate for creating an active learning environment. This theory emphasizes engaging in activities that promote active knowledge construction (Dogru & Kalender, 2007), enhancing higher-order thinking (Bogar et al., 2012), and training students to think critically, analytically, and forward-thinking (Boghossian, 2012). Form four students are categorized at the fourth stage, the formal operational stage, in their cognitive development as proposed by Piaget's Cognitive Constructivism Theory. At this stage, Piaget assumed that children's patterns of reasoning are complete, allowing them to use logic, comprehend concrete and abstract concepts, engage in reasoning, and solve problems through assumptions.

This module also emphasizes cooperative learning through group-based product-creation activities. In line with Social Constructivism Theory, Vygotsky also highlights the significance of cooperative learning, which is crucial in decision-making processes. This includes assigning tasks in pairs or small groups to maintain student motivation. This aligns with the implementation of this study, which divides the research subjects into small groups of 5 to 6 individuals. Vygotsky believed that for effective learning, students need to engage in self-talk in a motivating and guiding manner, gradually internalizing the spoken guidance. This way, students can develop and become more competent in specific areas. This internalized interaction forms the basis for teaching thinking skills (McLeod Saul, 2007).

Furthermore, Vygotsky's Social Constructivism Theory suggests the active involvement of students, aiding them in exploratory learning, providing guidance through explanations, demonstrations, and verbal instructions, as well as delivering information and cooperative learning. This theory emphasizes guided exploration by the teacher, where the teacher employs questioning methods to prompt students to seek answers to questions (Kubli, 2005). This principle also aligns with the implementation of this study, where the socio-scientific approach exposes students to social issues and encourages them to find scientific solutions. The posed questions act as guided explorations for the students. Although students engage in the exploration process, they still receive assistance from knowledgeable teachers and peers.

The researcher also acknowledges the significance of pedagogical principles in the teaching and learning

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process in secondary schools, supporting the cognitive and social construction of information and knowledge. This study employs the Socioscientific Issue Approach (SIA) Model (Sadler et al., 2017) and the Design Thinking (DT) Model (Adapted from Hasso Plattner Institute of Design at Stanford University, 2019).

According to Sadler et al. (2017), the SIA learning model encompasses three phases. In implementing the first phase, students discover or are introduced to a specific issue. Students are guided to engage in discussions about the stated issue, building their understanding by connecting it with scientific ideas and societal awareness. In the second phase, a process of scientific practice takes place, where students reason about the social and scientific components related to the issue from the first phase. In this case, students actively seek connections between the social issue, scientific knowledge, and scientific practices, making the issue more relevant for resolution (Sadler et al., 2017). Students strive to solve the issue based on societal values during the final phase. They are encouraged to synthesize ideas and practices and actively express ethical ideas and opinions.

The Socioscientific Issue Approach model is integrated with the Design Thinking (DT) model in creating this module. Plattner (2019) from the Institute of Design at Stanford University presented five stages of the DT learning model as a framework for solving real-world problems. These stages are empathize, define, ideate, prototype, and test. In the empathize stage, students seek to understand user needs to enable them to set aside their assumptions and gain direct insights into user needs (Chaudhari, 2021). Students gather user problems obtained during the empathize stage in the define stage. They then analyse, observe, and synthesize these problems to determine the core issues that require solutions. Students also formulate problem statements during this stage. Moving on to the third stage of the DT model, ideation, students focus on generating creative ideas and organizing solution ideas for the problem statements. Various ideation techniques such as Brainstorm, Brainwrite, and SCAMPER are employed. Brainstorming the Worst and Possible Ideas is usually used to stimulate free thinking, helping students develop the best solutions for users (Chaudhari, 2021). Subsequently, in the prototype stage, students are required to construct prototypes. At this point, students transform their solution ideas into tangible products. In the final stage, testing, students test and receive user feedback on the prototypes they have built. Feedback from the public, users, experts, and stakeholders enables students to decide if the prototype aligns with the defined problem-solving objectives or if an iterative process is necessary.

The researcher employs a comprehensive integration method (Swartz & Parks, 1994) to combine the socio-scientific issue approach with the design thinking model (SIA-DT). In this method, entrepreneurial creative thinking is identified beforehand and taught simultaneously with the subject content. Comprehensive integration is taught using five teaching steps: (i) introduction, (ii) active thinking, (iii) thinking about thinking, (iv) reinforcement exercises, and (v) application of thinking. In this context, both components (subject content and entrepreneurial creative thinking) are interrelated and implemented in each process.

For the design and development of the Entrepreneurial Creative Thinking teaching and learning module, the researcher adopted the ADDIE Model (Branch, 2010), which consists of five phases: analysis, design, development, implementation, and evaluation. The ADDIE Model was chosen because it centres on student-centred learning activities and goal-oriented instructional design and enables students to engage in meaningful actions and solve problems practically. The theoretical framework for the design and development of the Entrepreneurial Creative Thinking teaching and learning module is illustrated in Figure 1.

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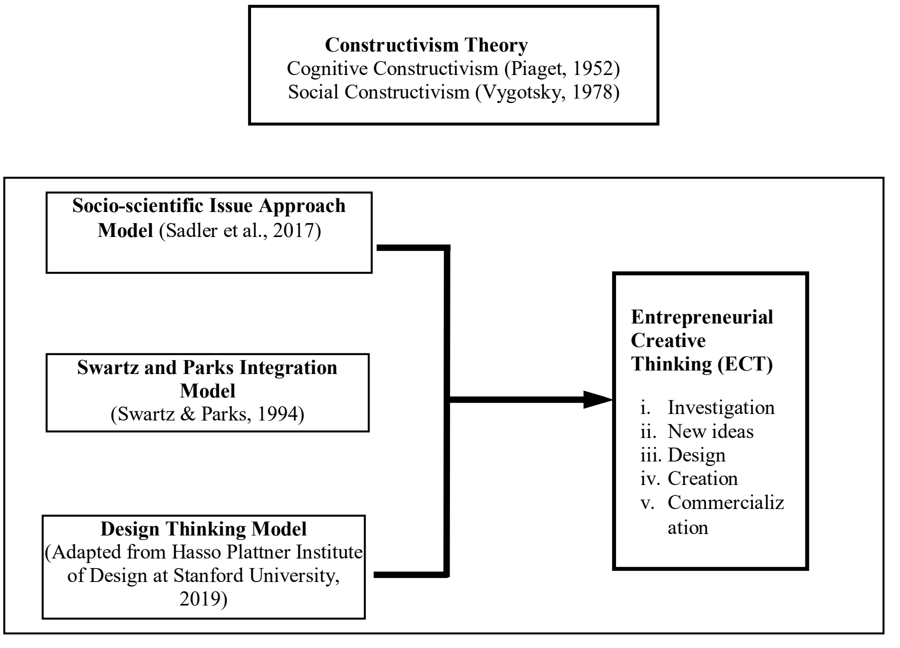
Figure 1
Theoretical Framework in the Design and Development of the Entrepreneurial Creative Thinking Teaching and Learning Module



Research Aim and Questions

This study was conducted to design and develop a teaching and learning module that integrates the socio-scientific issue approach and design thinking (SIA-DT) to enhance Entrepreneurial Creative Thinking (ECT) in STEM Education for Form Four students. There are three research questions that guide this study:

i. Is the developed ECT module valid, reliable, and feasible for Form Four students?
ii. Are there significant differences between pretest and posttest scores for the SIA-DT experimental group regarding entrepreneurial creative thinking and all constructs of entrepreneurial creative thinking?
iii. Are there significant differences in entrepreneurial creative thinking and all constructs of entrepreneurial creative thinking between Form Four students in the SIA-DT experimental group and the control group?

Research Methodology

Design

This study employs a descriptive and quasi-experimental research design. The descriptive study assesses the validity, reliability, and feasibility of the Entrepreneurial Creative Thinking (ECT) teaching and learning module. On the other hand, a quasi-experimental design is applied to determine the effects of the ECT module on the entrepreneurial creative thinking of Form Four students. The study was conducted for 12 weeks, from November 2022 to January 2023.

Sample

The descriptive study involves 32 Form Four students and three expert assessors. When assessing the reliability of a newly developed instrument, a sample size of 30 respondents is considered adequate (Chua, 2011). In the quasi-experimental study, a total of 64 Form Four students were involved. They were randomly selected from two rural secondary schools in Tawau, Sabah, Malaysia. These students were divided into the SIA-DT experimental group (*n*=32) and the control group (*n*=32). Among them, 28 (44%) were male, and 36 (56%) were female. About

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23% of the student's parents worked in the government sector, while the remaining 77% worked in the private and self-employed sectors.

Ethical Considerations

At the initial stage of the study, the researcher obtained consent from the principals, teachers, and students involved as research subjects. All research subjects were provided with informed consent letters to seek permission from their parents to participate in the research. The consent letter detailed the students' involvement in the research and the parental agreement, indicating their understanding of the research purpose. All respondents were informed about their responses' confidentiality and were assured that they could withdraw from the study without any penalty.

Descriptive Analysis

Analysis Phase

The main objective of developing this Entrepreneurial Creative Thinking (ECT) module is to nurture and enhance the entrepreneurial creative thinking of Form Four students in STEM Education taught within the Science subject. To achieve this instructional objective, the researchers conducted an analysis of student needs and the context. During the needs analysis phase, the researchers conducted semi-structured interviews with three Form Four science teachers in Tawau, Sabah, on November 15, 2022. These interviews aimed to understand how to enhance ECT within STEM education. Through these interviews, the Form Four science teachers indicated they had limited knowledge about implementing STEM in the Science subject. They stated that despite the media coverage of STEM, they had not received formal exposure to STEM implementation in their subject. They also acknowledged not understanding entrepreneurship concepts clearly and were only familiar with entrepreneurship through cross-curricular elements within the classroom. They also expressed their lack of understanding regarding the socio-scientific issue approach and design thinking. One of the interviewed teachers had heard of the socio-scientific issue approach but had not yet implemented it. All the teachers shared feedback that they lacked exposure to ECT concepts and its teaching process due to the absence of guidance or learning modules related to ECT implementation in secondary schools. The interviews also revealed that the teachers had not received any training or courses related to ECT.

In analysing the students and context, the criteria used were adapted from Carlton, Kicklighter, Jonnalagadda, and Shoffner's idea (2000), which focused on students' prior knowledge about Unit 1.1, "Personal Protective Equipment," and Unit 10.4, "Health Products," within two themes of the KSSM Form 4 Science Curriculum: "Safety and Health" and "Chemistry in Medicine and Health." A questionnaire was utilized to gather information about students' proficiency levels in drawing skills, product creation skills, and using digital technology for commercial purposes. A total of 30 students were selected to provide feedback for this analysis. The analysis results indicated that all the assessed criteria were at a moderate level.

Therefore, the findings from this interview have provided strong justification to the researcher for designing the ECT Module as a guide for secondary school teachers to enhance Entrepreneurial Creative Thinking (ECT) in STEM Education among secondary school students.

Design and Development Phase of ECT Module

The ECT Module is designed by adapting the socio-scientific issue approach, which involves introducing social issues to students, helping them analyse the social and scientific components of the issues, and encouraging them to find solutions based on societal values. To assist students in creating products to address the socio-scientific issues presented, the design thinking model is utilized as a guide. These models are integrated through the Swartz and Parks (1994) framework for integrating thinking.

This module has six activities, including daily lesson plans, issues, stimuli, implementation procedures, and activity scoring rubrics to assist teachers in the implementation process. These activities are built according to the latest Standard Curriculum and Assessment Document for Form 4 Science under the KSSM by the Ministry of Education Malaysia (MOE). A total of six learning units have been designed under the themes of Safety and Health

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and Chemistry in Medicine and Health for the Form 4 Science KSSM subject. These units include Fabric Face Cover, Face Shield, Face Mask, Paper Soap, Pocket Hand Sanitizer, and Wet Disinfectant Tissue. Each activity is allocated 135 minutes. However, the suggested time for conducting these activities can be adjusted according to the school's teaching and learning (TL) schedule, as the steps involving product creation and commercialization are often carried out outside of regular TL hours.

This module is developed to cultivate Entrepreneurial Creative Thinking (ECT) in the Science TL at secondary schools through five steps: (i) investigation (conducting an investigation focusing on socio-scientific issues while considering user needs), (ii) generating new ideas (seeking new ideas through socio-scientific reasoning that fulfils user needs), (iii) design (formulating new products through sketching), (iv) creation (constructing products based on societal values), and (v) commercialization (introducing products to the community through digital technology). These five steps are adapted from the SET model by Buang et al. (2009), extracted based on the integration of steps from the DT model and the socio-scientific approach, as illustrated in Table 1.

Table 1

Teaching Entrepreneurial Creative Thinking Through the Integration of Socio-scientific Issues and Design Thinking Process Model

Socio-scientific Issues Approach Model (SIA) (Sadler et al., 2017)	Process of Design Thinking (DT) Model (Hasso Plattner Institute of Design at Stanford University, 2019)	Integration of Socio-scientific Issues Approach (SIA) and Design Thinking (DT) Models
Phase 1 Identifying Issue Focus Building Understanding of Socio-Scientific Issue	**Building Empathy** Investigating and Understanding User Needs	**Investigation** Conducting an investigation focused on socio-scientific issues while considering user needs
	Determining Scope Synthesizing findings while considering user problems and needs	
Phase 2 Engagement Involving students in acquiring scientific knowledge, scientific practices, and socio-scientific reasoning practices	**Idea Generation** Creative generation and organization of ideas	**New Idea** Searching for new ideas through socioscientific reasoning that meets user needs
		Design Formulating new ideas through sketching
Phase 3 Synthesizing Ideas and Practices Resolving issues based on societal values	**Prototyping** Building a prototype	**Create** Building a product based on societal values
	Testing Testing the prototype to gather feedback from users	**Commercialization** Introducing the product to the public through digital technology

In planning the activities, the researcher identifies socio-scientific issues that trigger ideas at each step of the ECT, ultimately leading to product creation. A socio-scientific issue that resonates with students at this time is the outbreak of COVID-19. Issues related to the transmission of COVID-19 are highly relevant to be linked with unit 1.1 on safety equipment and unit 10.4 on health products under the Safety and Health theme and the Chemistry in Medicine and Health theme. Through the steps of ECT, students will attempt to solve the problems users face by creating personal protective equipment and health products that can help contain the spread of COVID-19 while meeting user needs. Some examples of socio-scientific issues provided are as follows:

> Nowadays, users are advised to use a germ-killing liquid containing alcohol levels between 60 to 80 per cent to eliminate germs on their hands' surfaces. Similarly, the same percentage is recommended for alcohol-free germ-killing liquids that use a chemical compound called quaternary ammonium, specifically benzalkonium chloride. Alcohol concentrations exceeding 80 per cent are less suitable due to their quick-drying nature, which can cause the skin to become dry and cracked. Among the types of alcohol-based chemical compounds used in germ-killing liquids are ethanol (ethyl alcohol), "rubbing alcohol," or "isopropyl alcohol." The application of the liquid is similar to handwashing, but the process is quicker because germ-killing liquids dry rapidly. For maximum effect, it is highly recommended to thoroughly wash hands to ensure there is no dirt hindering the germ-killing liquid when applied to the skin's surface. The question of how we can create a portable hand sanitiser convenient for users arises.

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Based on the given socio-scientific issue, students are required to create a product that addresses the problem using the guidance of the five steps of ECT. In the first stage, students investigate the socio-scientific issue by formulating questions to understand the issue, its relationship with science, and its relevance to society. Through engagement and discussions with the real-life community concerning the issue, students can set aside their assumptions and comprehend the community's needs or the problems that must be resolved.

In the second stage, students are provided with a foundation to actively engage in imaginative thinking and explore new ideas to solve the problem and meet user needs. Through socio-scientific reasoning practices, while considering user problems, students strive to present unique and original ideas.

In the third stage, students are encouraged to synthesize their ideas and design new products through sketching. Considering societal values, students creatively arrange their ideas and select a few that they believe are most suitable for solving user problems. These chosen ideas are then translated into sketches. In the fourth stage, students translate these sketches into actual product designs. The products they create are constructed using local raw materials deemed appropriate for the production of the products.

In the fifth stage, students test the product by obtaining user feedback and considering ways to commercialize the product. This stage involves branding the product, pricing strategies, determining distribution channels, and creating marketing campaigns through suitable digital market channels in line with the Fourth Industrial Revolution. At this stage, students apply basic digital marketing skills through product, price, place, and promotion strategies, aligning them with digital technology advancements to generate revenue.

Assessment Phase

The assessment phase is carried out to interpret evidence and the quality of the teaching product before and after its implementation (Branch, 2009). As suggested by Branch (2009), the assessment is conducted in two phases: before and after the implementation of the ECT Module. Cohen and Swedlik (2018) emphasise that a suitable module exhibits high validity and reliability.

In the first assessment phase, the researcher conducts expert validation of the content of the ECT Module. Rubio et al. (2003) recommended involving at least three experts in the field under study to ensure that the domains contained in the assessment instrument truly represent the studied area. The module assessment form is provided to the experts to enable them to provide clear feedback on pedagogical content (socio-scientific approach, design thinking, and STEM education), an overview of activities, the appropriateness of each lesson plan, learning standards, the overall sequence of activity units, the integration of the five steps of entrepreneurial creative thinking, and written comments to enhance the module.

The second assessment phase is conducted to assess the reliability and feasibility of the module. To ensure the reliability of the ECT Module, a questionnaire set adapted from Ahmad (2022) is provided to the 32 study subjects in the SIA-DT group after the intervention using the module is carried out. Aung et al. (2021) have indicated that questionnaires based on activities exhibit higher reliability indices compared to module objectives. The ECT Module comprises six activities, and each activity is assessed by five items using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The items address whether each activity conducted can help respondents cultivate the five constructs of entrepreneurial creative thinking following the module's learning outcomes. All 30 items are presented in a language that is appropriate and clearly understood.

To ensure the ECT Module's implementation in the TL for Form Four students, the researcher distributed a questionnaire to 20 Form Four science teachers. The teachers were requested to assess the feasibility level of the module by indicating their level of agreement on a scale from one to five for various aspects of the module, including the activities within the module, the integration of SIA and DT, and an overall assessment of the module.

Quasi-Experimental Study

The experimental research phase involves the implementation of the ECT teaching and learning module and assessing its effectiveness during classroom teaching and learning sessions. In line with this, the quasi-experimental Non-Equivalent Control Group Pre-Post Test design is used. A total of 64 Form Four students were randomly selected from two rural secondary schools in the Tawau district and divided into the experimental group (SIA-DT, n=32) and the control group (n=32). The research subjects in the experimental group received the ECT module, which covers

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six learning units over 12 weeks from November 2022 to January 2023. Each learning unit in this module consists of three sessions that take 180 minutes. A total of 6 teaching periods per week (180 minutes) were allocated for Form Four science lessons, each lasting 30 minutes. The researcher suggests that teachers complete one set of learning units in the ECT Module for two weeks. One week is dedicated to implementing the steps in the module, while the second week involves creating and producing marketing advertisements through digital technology. Teachers can also conduct module activities outside the formal teaching periods, depending on availability. On the other hand, students in the control group are exposed to the conventional design model production method without incorporating the socio-scientific issue approach and design thinking model.

To assess the module's effectiveness, the Entrepreneurial Creative Thinking Test (ECTT) instrument developed by the researcher was utilized. This instrument has been validated, proven reliable, and deemed suitable for evaluating the entrepreneurial creative thinking of Form Four students. The ECTT consists of 10 items that require students to respond to statements, generate idea sketches, and propose product marketing strategies using technological elements. The items were developed based on the five constructs of Entrepreneurial Creative Thinking. The ECTT prompts students to address the issue of using face shields and masks separately and in combination. The context of producing a combination of face shields and masks was chosen as it is included in the Curriculum and Assessment Document under the Safety and Health theme. Students were provided with ten-item questions organized according to the five ECT constructs—investigation, new idea generation, design, creation, and commercialization—to enable them to structure their responses and consequently lead to the desired outcomes. Scoring for the ECTT was conducted based on the scoring scheme by Ho et al. (2013). Each item presented in this test carried a minimum score of 0 and a maximum score of three. Meanwhile, the scores for each construct ranged from 0 to 6. All items accumulated a total score of 30.

Data Analysis

Descriptive study data was obtained by calculating percentages, means, and standard deviations. On the other hand, inferential study data was obtained through analysis using IBM SPSS (version 26). For this analysis, the significance level was set at .05.

Research Results

Content Validity

The researcher utilized the services of three expert individuals in entrepreneurial thinking, design thinking, and STEM education. In determining the experts' agreement on content validity, the researcher also employed the Content Validity Index (CVI) based on each item on the scale (I-CVI) as well as the overall scale (S-CVI/Ave), following the approach outlined by Polit et al. (2017). The obtained Content Validity Index Item (I-CVI) values for the standard assessment and learning outcomes aspects were below .78. This suggests that the standard assessment and learning outcomes aspects need refinement based on expert group comments and suggestions. The Content Validity Index Scale (S-CVI/Ave) value of .93 for the entire module meets the criteria set for new instruments, indicating that the content validity of the ECT Module, according to the expert panel, is high and acceptable (Polit et al., 2017).

In line with the experts' recommendations, several improvements have been made to the content and activities of the ECT Module; 1) The activities should incorporate an introduction to current issues to help students understand the relevance of the topics under discussion, 2) The term 'marketing' needs to be reviewed and revised, 3) The alignment of learning standards with learning outcomes for Units 1-3 should be ensured, 4) Clear explanations regarding product marketing activities should be included, and 5) Illustrations and supplementary materials need to be added to each unit in accordance with the demands of core values, similar to those found in textbooks.

Reliability

The module's reliability can be determined when study participants can master the objectives and effectively follow the steps for each activity in the module at a satisfactory level. Most researchers suggest that an alpha coefficient greater than .8 indicates high reliability (Bogden & Milken, 2003; Sekaran & Bougie, 2010). Preliminary research results indicate that the Cronbach's Alpha values for all units within the module range from .74 to .88,

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with an overall Cronbach's Alpha value for the ECT module of .82. This demonstrates that the internal consistency of the developed ECT module as a whole is high.

Table 2
The Cronbach's Alpha value of the ECT Module

Unit	Unit within the module	Cronbach's Alpha
1	Face mask fabric	.88
2	Former face mask	.87
3	Face mask	.84
4	Hand wash soap	.77
5	Hand sanitizer	.86
6	Disinfectant wet wipes	.74
	Average	.83

Feasibility

To ensure this ECT Module's implementation in the TL for Form Four students, the researcher distributed a questionnaire to 20 Form Four science teachers. The teachers were asked to assess the feasibility level of the module by indicating their agreement level on a scale from one to five for aspects related to module activities, integration of SIA and DT, and overall assessment of the module. Table 3 presents the teachers' assessment of the feasibility of the module.

Table 3
Teacher Assessment of the Feasibility of the ECT Module

Unit	Feasibility Criteria	*M*
1	Activity implementation	4.65
2	Integration of SIA and DT	4.76
3	Overall module	4.71
	Average	4.71

Junus et al. (2021) stated that criteria with a minimum threshold of 3.50 indicate that the feasibility aspect of the module is acceptable. However, if the minimum threshold is below 3.50, changes need to be made as the feasibility aspect of the module is considered unsatisfactory. Overall, teachers provided assessments ranging from 4.65 to 4.76 for all three criteria related to the feasibility of the module. A minimum of 4.71 indicates that teachers agree that the ECT Module can be implemented in schools to foster ECT among Form Four students.

Effectiveness of the ECT Module

The Entrepreneurial Creative Thinking (ECT) Module was tested on 32 students in a rural secondary school in Tawau, Sabah. Students were given the Entrepreneurial Creative Thinking Test (ECTT) to assess their entrepreneurial creative thinking before and after the intervention using the ECT module. Inferential data analysis was conducted using paired samples t-test to determine whether there were significant differences between pre-test and post-test scores for the study subjects who underwent the SIA-DT intervention. Table 4 presents the results of the paired samples t-test analysis for the SIA-DT experimental group. The analysis indicates significant differences for pre-test and post-test scores in entrepreneurial creative thinking (t (31) = -20.605, $p < .05$), Investigation construct (t (31) = -12.175, $p < .05$), New Idea construct (t (31) = -13.373, $p < .05$), Design construct (t (31) = -13.638, $p < .05$), Create construct (t (31) = -15.033, $p < .05$), and Commercial construct (t (31) = -12.938, $p < .05$).

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Table 4
Results of the Independent Samples t-Test for the SIA-DT Experimental Group

Construct	Test	*M (SD)*	*MD (SD)*	*t*	*df*	*p*
ECT	Pre	11.59 (3.221)	-14.156 (3.886)	-20.605	31	< .05
	Post	25.75 (2.185)				
Investigation	Pre	2.47 (1.077)	-2.656 (1.234)	-12.175	31	< .05
	Post	5.13 (.707)				
New Idea	Pre	2.16 (1.139)	-3.031 (1.282)	-13.373	31	< .05
	Post	5.19 (.738)				
Design	Pre	2.13 (1.100)	-3.000 (1.244)	-13.638	31	< .05
	Post	5.13 (.707)				
Create	Pre	2.25 (.916)	-2.937 (1.105)	-15.033	31	< .05
	Post	5.19 (.738)				
Commercial	Pre	2.59 (.875)	-2.531 (1.107)	-12.938	31	< .05
	Post	5.13 (.707)				

Note: Significance level at $p = .05$

Table 5, on the other hand, presents the results of the Independent Samples t-Test analysis between the experimental group and the control group. The Levene's test for equality of variances was not significant for ECT ($p = .236$, $p > .05$), Investigation construct ($p = .171$, $p > .05$), New Idea construct ($p = .337$, $p > .05$), Design construct ($p = .129$, $p > .05$), Create construct ($p = .420$, $p > .05$), and Commercial construct ($p = .109$, $p > .05$), indicating that both the experimental and control groups have equal variances.

The analysis results indicate that the study subjects in the SIA-DT experimental group have significantly higher post-test scores compared to the control group in terms of the Entrepreneurial Creative Thinking (ECT) aspect ($t(62) = 21.962$, $p < .05$), Investigation construct ($t(62) = 9.390$, $p < .05$), New Idea construct ($t(62) = 13.904$, $p < .05$), Design construct ($t(62) = 11.988$, $p < .05$), Create construct ($t(62) = 16.812$, $p < .05$), and Commercial construct ($t(62) = 6.696$, $p < .05$). These results demonstrate that there is a significant difference in post-test scores for students in the SIA-DT group compared to the control group in terms of entrepreneurial creative thinking and all five constructs of entrepreneurial creative thinking.

Table 5
Results of the Independent Samples t-Test for the experimental Group and the Control Group

Construct	Experimental Group *M* *(SD)*	Control Group *M* *(SD)*	*MD* *(SD)*	*t*	*df*	*p*
ECT	25.75 (2.185)	14.25 (2.000)	11.500 (.524)	21.962	62	< .05
Investigation	5.13 (.707)	3.13 (.976)	2.000 (.213)	9.390	62	< .05
New Idea	5.19 (.738)	2.28 (.924)	2.906 (.209)	13.904	62	< .05
Design	5.13 (.707)	2.72 (.888)	2.406 (.201)	11.988	62	< .05

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Construct	Experimental Group *M* *(SD)*	Control Group *M* *(SD)*	*MD* *(SD)*	*t*	*df*	*p*
Create	5.19 (.738)	2.09 (.734)	3.094 (.184)	16.812	62	< .05
Commercial	5.13 (.707)	4.03 (.595)	1.094 (.163)	6.696	62	< .05

Discussion

This study aimed to assess the developed module for enhancing entrepreneurial creative thinking among Form Four students. The development of the ECT module was geared towards meeting the needs of students in the face of the Fourth Industrial Revolution. Assessments of its validity, reliability, feasibility, and effectiveness were analysed to ensure its feasibility in schools. The ECT module was constructed based on a clear and detailed theoretical framework, incorporating the Socio-scientific Issues Approach and the Design Thinking Model by integrating the Swartz and Parks Integration Model (1994) to examine the effects on the five constructs of Entrepreneurial Creative Thinking.

Overall, the study findings have demonstrated that the ECT module possesses good content validity and is feasible for enhancing entrepreneurial creative thinking among Form Four students. Analysis regarding the content validity of the module has shown that the three expert assessors well-received the ECT Module, with several improvements made to various aspects within the module. Reliability analysis indicates that the ECT module falls within an acceptable range based on Cronbach's alpha values. This study has confirmed that the integration of the Socio-scientific Issues Approach, Design Thinking Model, Swartz and Parks Integration Model (1994), entrepreneurial creative thinking model, and the ADDIE instructional design model verifies the legitimacy and reliability of the ECT Module for implementation in STEM-based pedagogical practices.

The results of the paired-sample t-test indicate that Form Four students in both the SIA-DT and control groups exhibited better performance in the five constructs of entrepreneurial science thinking in the post-test compared to the pre-test. However, Form Four students in the SIA-DT group demonstrated a significantly larger improvement in scores compared to their peers in the control learning group. This signifies that the opportunity to learn with the ECT teaching and learning module profoundly impacts the entrepreneurial creative thinking of Form Four students. As for the independent samples, t-test results suggest that using the ECT teaching and learning module effectively nurtures ECT and the five constructs of ECT.

Exposure to socio-scientific issues in the ECT module enables students to connect these issues with their personal experiences. Engaging in arguments about socio-scientific issues alongside inquiry encourages students to form preliminary ideas about the conceptualization of the product to be created, provides a clear understanding of the subsequent steps to take, and assists students in easily seeking answers to the issues or problems they encounter (Mutvei et al., 2017). Schmidt et al. (2013) emphasize that effective inquiry focuses on problem-solving rather than problem-finding. This is consistent with Fillis and Rentschler (2010), who assert that entrepreneurial creative thinking should prioritize the continuous creation of alternative solutions to address problems and identify new opportunities.

Furthermore, exposure to socio-scientific issues through the ECT Module aids in developing skills such as decision-making, evaluating statements, analysing evidence, and assessing various perspectives through discussions and debates (Sadler & Zeidler, 2005; Zeidler, 2016; Zeidler & Nichols, 2009) within the context of the real world. In this regard, students nurtured through SIA will be more adept at analysing and solving problems precisely. Moreover, the scientific knowledge generated through debating socio-scientific issues encourages students to generate ideas more effectively towards finding solutions to societal problems, thereby enhancing entrepreneurial thinking among students (Kinslow et al., 2017). Aligned with the socio-scientific issues addressed in each activity unit, these issues allow students to analyse and provide input, enabling them to create product innovations that address the issues raised.

Additionally, the increase in minimum scores among students participating in SIA-DT compared to control group can be elucidated through the highly detailed approach to socio-scientific issues (Topçu et al., 2018). In the initial phase of the socio-scientific issues approach, which engages students in issue-focused activities, students

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investigate the matters discussed within the issues. Subsequently, in the second phase involving connecting scientific ideas and relating to societal sensitivities, students pose questions among group members, link experiences to discoveries, acquire new knowledge, and establish connections between events or objects. The utilization of the socio-scientific issues approach, supported by the design thinking model, aids in enhancing students' entrepreneurial creative thinking levels. This is because the discussions surrounding socio-scientific issues lead to a step-by-step product generation process, as exposed by the design thinking model (Mutvei et al., 2019).

The integration of the socio-scientific issues approach with the design thinking model also encourages students to think outside the box and generate innovative ideas when seeking critical problem solutions (Aung et al., 2021). Therefore, design thinking can address ambiguous problems (Aung et al., 2021; Buchanan, 2001). Such problems can be effectively solved by employing high-level thinking skills. According to the revised Bloom's Taxonomy educational objectives (Anderson et al., 2001), design thinking encompasses all cognitive activities, including remembering, understanding, applying, analysing, evaluating, and creating (Powell & Kalina, 2009).

The degree of improvement in students' entrepreneurial creative thinking levels across all five constructs using the SIA-DT method as opposed to the conventional method is facilitated by the systematic integration of SIA and DT. Kinslow and Sadler (2018) and Sadler et al. (2017) also support that combining SIA with other instructional models enhances students' scientific knowledge as they explore socio-scientific issues. The debate of socio-scientific issues leads to discussions of ideas that expand scientific knowledge and its implications within society, ensuring deep understanding to make well-informed decisions. Consequently, SIA guides the appropriate decisions when selecting the best new ideas for further development into student-created products (Sadler & Zeidler, 2005; Zeidler, 2016; Zeidler & Nichols, 2009).

Indeed, implementing the ECT aims to cultivate creative entrepreneurs prepared to face the challenges they will encounter when designing and launching new ventures. Therefore, integrating the ECT into students' education through training and experiences in schools will produce students who can think entrepreneurially, identify market opportunities, and explore suitable ways to market the product (Bacigalupo et al., 2016). Students equipped with entrepreneurial creative thinking will consistently exhibit innovation in problem-solving (Nadelson et al., 2018). In other words, integrating the ECT into learning activities and instructional facilitation within the classroom can foster individuals capable of innovating and commercialising new ideas or products by leveraging existing opportunities.

Conclusions and Implications

This study confirms that the developed ECT teaching and learning module exhibits acceptable reliability and content validity. Overall, the ECT module is feasible to foster the entrepreneurial creative thinking among Form Four students. The study shows that the integration of the socio-scientific issues approach and design thinking model in developing the ECT module has effectively increased student entrepreneurial creative thinking. This study demonstrates that a carefully designed integrated approach for teaching ECT enables students to investigate the socio-scientific issues, generate new ideas, design, create and commercialize products in order to address the raised issues with the assistance of systematic steps within the design thinking model.

The present research findings draw the two implications for current STEM education practices. First, the existing STEM education usually adopts a particular teaching approach or model which cannot help promote the diversity and comprehensiveness of the STEM education to foster student's entrepreneurial creative thinking. Teachers should actively explore new integrated teaching approach to make the curriculum more meaningful to students. Second, teachers need continuous professional development to improve their ability to utilize new integrated teaching approach. Educational administrations should provide teachers with training and resource support and encourage them to innovate their teaching approach. At the same time, teachers need to upgrade themselves to better meet the demands of 21st Century education.

The future development of teaching and learning module requires the joint efforts of teachers, schools, and administrations to create a supportive atmosphere for innovations in integrated teaching approach to effectively stimulate students' entrepreneurial creative thinking in STEM education.

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Limitations and Future Research

This study has two limitations that provide avenues for future research in the assessment of the ECT Module. First, this study was a one-time study in the specific context of STEM education for Form Four students in two secondary schools. Therefore, the findings may not be applicable to different age groups. Second, the data analysis was based on the interpretation of the statistical results which lacked in-depth narrative evidence such as interviews to support the triangulation and coding results of classroom observations. As a result, future researchers are recommended to replicate the study in more diverse contexts; and to focus on a variety of empirical data, including observations, interviews, and document analyses.

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Declaration of Interest

The authors declare no competing interest.

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