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GLOBAL ACADEMIC EXCELLENCE

AN ENTREPRENEURIAL CREATIVE THINKING TEST FOR HIGH SCHOOL STUDENTS IN STEM EDUCATION

Sufirman Arifin[1], Nyet Moi Siew[2*]

[1] Fakulti Psikologi dan Pendidikan, Universiti Malaysia Sabah, Malaysia
Email: sufirman. arifin@gmail.com
[2] Fakulti Psikologi dan Pendidikan, Universiti Malaysia Sabah, Malaysia
Email: sopiah@ums.edu.my
[*] Corresponding Author

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Abstract:

Instruments have been developed to measure entrepreneurial thinking. However, those instruments did not assess the commercial aspects of product marketing using digital technology. Consequently, the Entrepreneurial Creative Thinking Test (ECTT) was developed to assess the level of entrepreneurial creative thinking among Form Four high school students in STEM education. ECTT consists of five constructs derived from integrating the steps between the Socioscientific Issue Approach Model and the Design Thinking Process Model. The five constructs are Investigation, New Idea, Design, Create, and Commercial. The sample consisted of 187 Form Four students aged 15 to 16 years from four high schools in Sabah, Malaysia. The sample comprised 103 females (55.1%) and 84 males (44.9%). A survey research design was conducted to ascertain the extent to which the validity and reliability of this instrument can meet the psychometric characteristics of a research. The survey research design focused on the validity and reliability assessment of ten open-ended questions. This study utilised the Rasch Measurement Model to evaluate the validity and reliability of the ECTT instrument. Person fit, item fit, item polarity, unidimensionality, reliability, and item-person separation were analysed. The study's findings revealed that the ECTT instrument has good item reliability, with a score of .97. In conclusion, the ECTT is a valid and reliable instrument for assessing the level of entrepreneurial creative thinking among Form Four students in STEM education.

Keywords:

Entrepreneurial, Creative Thinking, Validity And Reliability, Rasch Measurement Model, STEM Education

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Introduction

Entrepreneurial thinking began to gain attention and was identified as one of the skills students must master (Bacigalupo et al., 2016) to produce human capital capable of innovation and skilled in applying technology in line with Industrial Revolution 4.0. Therefore, the education agenda of today must emphasise the development of human capital characterised by entrepreneurialism, critical thinking, the ability to generate creative and innovative ideas, and high ethical standards (Ministry of Education Malaysia, 2013).

Buang et al. (2009) have proposed entrepreneurial science thinking (EST) as a combination of science process skills and entrepreneurial thinking. The five components of the EST framework are Investigation, New Ideas, Innovation, Creation, and Value. Nonetheless, the EST framework requested students to collect feedback from the community on the product via questionnaires. The survey analysis was then presented to their classmates before the class. However, students were not instructed on introducing their products to the market using digital technology.

Consequently, Entrepreneurial Creative Thinking (ECT) is researched in this study, in which students implement product commercialisation activities utilising digital technology. According to Perry-Smith and Coff (2011), ECT produces novel or uncommon concepts that can generate market value. Della Corte and Del Gaudio (2017) stressed that the acceptance of a product idea in the market as a consequence of commercialisation is the true foundation of entrepreneurial creative thinking.

Integrated STEM Education concentrates on solving local community problems requiring all STEM disciplines, as well as non-STEM knowledge, such as effective communication via digital technology channels. Students learn how to commercialise ideas resulting from the integration of STEM and non-STEM disciplines through the development of ECT in integrated STEM education. Therefore, nurturing students' ECT through an integrated STEM education is important in order to produce students who can generate income through the creative commercialisation of their ideas via digital technology.

In order to cultivate this ECT, there is a need for an instrument capable of measuring students' entrepreneurial creative thinking. As far as this research is concerned, however, few instruments were developed to measure ECT accurately. Bolton and Lane (2012), Al Mamun et al. (2017) and Kurniawan et al. (2019) developed an instrument for measuring an individual's entrepreneurial orientation. Next, Saputra et al. (2021) created an instrument for assessing entrepreneurial character. The instrument devised by Ahmad and Siew (2021) measures only the level of entrepreneurial science thinking. All of these instruments are deemed to disregard the creative element of entrepreneurship. Consequently, a new instrument needs to be developed to assess high school students' entrepreneurial and creative thinking levels.

Research Problem

In carrying out Malaysian school classroom assessments, students' thinking and mastery are measured based on mastery levels 1-6. The highest mastery level is Mastery Level 6, where students are assessed based on the ability to create something as contained in the Malaysian Curriculum and Assessment Standard Document. Creating is one of the important elements in entrepreneurial thinking because it involves the creation of products based on the values of science, technology and society. Based on the Form Four Science Classroom Assessment

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Achievement Report in high schools in Tawau (Tawau District Education Office, 2021), the number of students who reached Mastery Level 6, which is the creative level in Science, is the lowest compared to other Mastery Levels. The percentage of students who reach Level 6 is only 3 %, which is far behind compared to Levels 3 (36 %) and 4 (39%). Nevertheless, it was found that 30% of Tawau's rural schools showed an encouraging achievement of Mastery Level 6 compared to urban schools. This shows that rural high school students have the potential to develop entrepreneurial thinking compared to urban high school students in the district.

There are claims that STEM education does not provide sufficient opportunities for students to acquire the skills needed in the 21st century (Jonassen et al., 2006). In order to meet the demands of a knowledge-based economy, STEM students must be adept at problem-solving, creative thinking, communication, teamwork, and commercialisation (Bilén et al., 2005; Jonassen et al., 2006; Passow & Passow, 2017). Students in high school should therefore master the five ECT constructs of Investigation, New Ideas, Design, Creation, and Commercialisation. Students are able to be trained to solve problems, generate ideas, communicate, work in teams, and commercialise their innovative products through exposure to the five constructs of ECT.

Although entrepreneurial thinking has been incorporated into the Malaysian curriculum, the development of instruments to assess the level of entrepreneurial thinking among high school students in STEM education is not yet widespread (Buang et al., 2010; Syukri et al., 2013). Previously developed instruments measured only the readiness for the integration of entrepreneurial science thinking (Ishak et al., 2014) and teacher pedagogical knowledge in teaching entrepreneurial science thinking (Syukri et al., 2013). Li et al. (2016) developed an instrument for measuring entrepreneurial thinking among engineering students. The instrument was developed based on the Kern Entrepreneurial Engineering Network (KEEN) framework specialises in engineering. The instrument focuses on three aspects, namely Curiosity, Connections, and Creating Value. The instrument reduced its items from 37 items to 29 items after the validity and reliability analysis using exploratory factor analysis. Unfortunately, the items do not reflect the development of new ideas and positive values in students' products.

Bolton and Lane (2012) developed an Individual Entrepreneurial Orientation (IEO) instrument for assessing entrepreneurial thinking among 1,100 university students. Using exploratory factor analysis, it was determined that the instrument was reliable and valid for measuring three of the five dimensions: innovativeness, risk-taking, and proactivity. However, the measurements in these three dimensions are relatively limited. The students' observation of current materials and designs, as well as the contribution of inventions to society, was not evaluated. In addition to assessing entrepreneurial thinking, Schelfhout et al. (2016) developed an instrument for evaluating entrepreneurial competence based on a behavioural indicator scale. The instrument was designed with 11 sub-competencies to assess high school students' competence and entrepreneurial thinking. Recently, Ahmad and Siew (2021) have also developed an instrument that measures entrepreneurial science thinking among primary school students. The instrument was developed based on the Entrepreneurial Science Thinking Model by Buang et al. (2009), which involves the constructs of observation, new ideas, innovation, creativity and value. However, this instrument did not assess the commercial aspects of product marketing using digital technology. According to Della Cortina and Del Gaudio (2017), a novel concept can only be valuable if it is market-acceptable.

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To sum up, few and limited instruments target the commercial aspects of entrepreneurial creative thinking for high school students in STEM education. Consequently, developing and utilising an instrument for this purpose is necessary. In accordance with this, the Entrepreneurial Creative Thinking Test (ECTT) was developed, and its validity and reliability were assessed to ensure that it can be used to measure entrepreneurial creative thinking among Form Four high school students in STEM education.

Literature Review

Entrepreneurial Creative Thinking

The definition of creative thinking in entrepreneurship can be derived by combining two broad terms: creative thinking and entrepreneurship. Creative thinking is a cognitive process to generate original, valuable, and beneficial ideas for further investigation (Sternberg, 2003). De Bono (1998) defines creative thinking as thinking that generates something that has never existed before, whereas Amabile et al. (1996) define creative thinking as thinking that leads to well-reasoned decisions. Creative thinking is a means of thinking that can generate new and valuable ideas (Sternberg, 2003). According to Rawlinson (2017), creative thinking can connect previously unrelated things or concepts.

Entrepreneurship is defined as all activities associated with the establishment and administration of a business, such as starting a company, managing business operations, product production, and marketing (Kucuk, 2017). Entrepreneurship is a practice that results in the creation of new businesses, goods, and values (Watts & Wray, 2012). Entrepreneurship also involves the exploration of potential resources, the discovery process, the utilisation of opportunities, and the exploitation of such opportunities (Bacigalupo et al., 2016). In other words, entrepreneurship is the ability of an individual to transform his/her ideas into reality based on the available opportunities.

Creative thinking is an essential component or the heart of the entrepreneurial process (Goss & Sadler-Smith, 2018), particularly in a more dynamic market context (Zhou, 2008), because it helps entrepreneurs succeed in the competition. Fortwengel et al. (2017) asserted that creative thinking is essential in the entrepreneurial process because it encourages entrepreneurs to seize or create opportunities. Some academics view creative thinking as a flexible approach required for entrepreneurial challenges (Fillis & Rentschler, 2010) that can assist in the generation of alternative solutions.

Although creative thinking is necessary for generating new ideas, not all are marketable and capable of adding value. The concept may have been introduced too early, or it may be too novel for the market to adopt (Perry-Smith & Coff, 2011). A novel concept can only be valuable if it is accepted by the market (Della Corte & Del Gaudio, 2017). Therefore, entrepreneurial creative thinking (ECT) is a person's capacity to produce superior products or services, processes or practises that contribute value to the market (Dayan et al., 2013). ECT can also be defined as producing novel or uncommon ideas that generate market value (Perry-Smith & Coff, 2011). Entrepreneurial Creative Thinking (ECT) is defined by Perry-Smith and Coff (2011) as the production of uncommon or original ideas that can generate market value. Della Corte and Del Gaudio (2017) defined ECT as the generation of market-acceptable new ideas. Therefore, in the context of this study, ECT refers to the commercialisation of novel products that can solve consumer problems. This concept was used when developing the question items

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in the Entrepreneurial Creative Thinking Test (ECTT). The ECT process in this study consists of five stages derived from the integration of the steps between the Socioscientific Issue Approach Model (Sadler et al., 2017) and the Design Thinking Process Model (Plattner, 2019) (Table 1). The constructs of ECT consist of Investigation, New Ideas, Design, Create and Commercial.

Table 1: Entrepreneurial Creative Thinking Through the Integration of Socioscientific Issue Approach Model and Design Thinking Process Model

Socioscientific Issue Approach (SIA) Model (Sadler et al., 2017)	**Design Thinking Process (DTP) Model (Plattner, 2019)**	**Entrepreneurial Creative Thinking Through the Integration of SIA and DTP Model**
Phase 1: Finding the Focus of the Issue Build an understanding of socioscientific issues	**Building Empathy** Investigate and understand user needs	**Investigation** Conduct investigations by focussing on socioscientific issues, taking into account the needs of users
	Defining Scope Synthesise findings by considering user problems and needs	
Phase 2 Engagement Student involvement in the acquisition of science knowledge, science practice and socioscientific reasoning practice	**Ideation** Creative generation and formulation of ideas	**New Ideas** Finding new ideas through socioscientific reasoning that meet user needs
		Design Formulate new ideas through sketches
Phase 3 Synthesising Ideas and Practices Solving issues based on societal values	**Prototype** Building a prototype	**Create** Creating products based on community values
	Testing Testing prototypes to get feedback from users	**Commercial** Introducing products to the community through digital technology

Rasch Measurement Model

The Rasch Measurement Model (MPR) is a psychometric technique designed to increase the precision of constructed instruments, monitor instrument quality, and compute respondent performance (Boone, 2016). Boone et al. (2011) also explained that MPR is a more informative scale analysis than the existing scale analysis in science education literature.

In addition, MPR provides extensive guidance for assessing science education instruments' validity and reliability (content, construct, accuracy, and expectation). The Rasch Measurement Model provides the researcher with information regarding the reliability of respondents and items, the separation of items and respondents, and Cronbach's Alpha values. In the meantime, the construct validity of an instrument can be evaluated based on the relevance of its items and respondents, as well as its unidimensionality (Waugh, 2012).

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Rasch analysis is able to provide a deeper comprehension of the instrument's strengths and weaknesses (Boone & Scantanbury, 2005), even though it may require a longer process than conventional analysis. Bond & Fox (2007) state that MPR is an efficient method for developing extraordinarily valid and reliable instruments through statistical analysis. The researcher used Rasch analysis to evaluate the validity and reliability of the ECTT instrument in light of these cited advantages.

Research Methodology

Design

A survey research design utilising a test instrument was used to collect data on the level of entrepreneurial creative thinking among Form Four students. A survey research design is well-established in education because it can analyse topics and constructs economically and efficiently (Creswell & Creswell, 2017). The information from the ECTT instrument centred on the Form Four students' experiences incorporating entrepreneurial elements into STEM project-based learning. This study was conducted between June and August of 2022.

Sample

The ECTT was administered to 187 samples among Form Four high school students in the Tawau district of Sabah, Malaysia. Linacre (2012) found that a sample size with a range of 108-243 is sufficient to measure the item's difficulty within 1/2 logit of its stable value with 99% confidence. The research sample consisted of rural school clusters comprised of similarly situated institutions. The students consisted of 103 females (55.1%) and 84 boys (44.9%) between the ages of 15 and 16 years old. Approximately 60% of parents were government employees, while 40% were working for a small business and industry sectors such as palm oil. The majority of the parents are made up of the Bajau, Suluk, Ida'an and Bugis tribes as well as the Chinese. This shows the uniqueness of students in Tawau compared to other geographical areas in Malaysia.

Ethical Considerations

Before administering the ECTT, written consent was obtained from the parents and school administrators. An initial outline of the ECTT's purpose, which was to assess the level of entrepreneurial creative thinking, was provided. The consent letter described the Form Four students’ participation in the research and the parents' comprehension of the study's purpose. All the students were guaranteed the confidentiality and anonymity of their responses. Students were also informed that withdrawal from the study was permitted without penalty. Then, a subsequent briefing was conducted to explain the guidelines and procedures for answering queries in ECTT.

Administration of ECTT

Each student was instructed to thoroughly read the instructions before answering the ECTT based on his or her knowledge and without assistance from other students. The students related current information, insights, and experiences in answering questions pertaining to issues that take user needs into consideration, the formation of new ideas, the production of sketches, the construction of products based on community values, and the introduction of products through digital technology. The Form Four students were given one hour to formulate their responses. The answers were collated and reviewed to ensure that the students followed the instructions

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correctly and provided complete responses before the data were analysed using WINSTEPS software version 3.73,

Instrumentation
Open-ended questions were used to measure each individual's entrepreneurial creative thinking. The use of open-ended questions can help in obtaining variations in respondents' ideas (Chen et al., 2020), provide an overview of respondents' level of knowledge (Clarke & Holt, 2019), and help researchers identify misconceptions among respondents (Schuetz, 2010). Researchers constructed open-ended questions based on the five constructs of ECT: Investigation, New Ideas, Design, Create, and Commercial.

This ECTT contains ten open-ended questions. The items are divided into five constructs of entrepreneurial creative thinking: (i) Investigation (2 items), ii) New ideas (2 items), iii) Design (2 items), iv) Create (2 items), and v) Commercial (2 items) with a recommended answer time of 60 minutes (6 minutes for each item and sub-item). Table 2 shows the items for the ECTT Test according to the construct.

Table 2: Items for ECTT by Construct

Construct	Definition	Item No.	Item statement
Investigation	Unravelling problems and user needs based on socio-scientific issues.	1a	Based on the issues mentioned, what are the three (3) problems that potential users face when using a combination of face mask and face shield?
		1b	In your opinion, what are the three (3) factors that can encourage users to use a combination of face mask and face shield?
New Ideas	Finding unique and different ideas from the market through socioscientific reasoning that can meet consumer needs	2a	Based on your answers to 1(a) and 1(b), suggest three (3) features of face masks that users need.
		2b	Based on the characteristics you presented in 2(a), come up with a new idea for a face mask and face mask combination that has three (3) unique features.
Design	Formulate new ideas through sketches and then evaluate their feasibility	3a	Translate your new product idea into a sketch in the space provided below. Label the sketch of the product.
		3b	Give a suitable name for your new product. Give three (3) justifications for choosing that name.
Create	Implement an idea or produce a new product that has been sketched	4a	Describe the production process of your new product in the space provided below.
		4b	Is your new product manufacturable? Give three (3) reasons for your answer.
Commercial	Introducing and marketing their new	5a	What is the selling price of your new product? Explain the three (3) rationales for setting the price.

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	products through digital technology	5b	What digital marketing strategy will you use to promote your new product? Explain three (3) reasons why you chose the digital marketing strategy.

The first is the investigation construct, which requires students to conduct investigations by deciphering socioscientific problems and user requirements. Based on the specified issues, students must investigate three problems potential users encounter when combining a face mask and a face shield. The second assignment required students to investigate three factors that can encourage the use of a combination of facial masks and face shields. The third and fourth items pertain to the New Ideas construct, which entails discovering unique and distinct consumer-focused ideas from the market through socioscientific reasoning. Based on their responses to questions 1(a) and 1(b), students must suggest three features of face masks that consumers require. Then, based on the characteristics presented in 2(a), students must develop a new concept for a face mask and face mask combination with three distinct characteristics. In the following step of the design process, students are required to sketch new concepts. The fifth item requires students to translate their new product concept into a design and label it. Then, they create an appropriate name for the new product and provide three justifications for choosing it. This follows the Create construct that requires students to implement an idea or generate a newly sketched product. The seventh item required students to describe the production process of the new product in the space provided, while the eighth item required them to defend the manufacturability of the new product. As part of the Commercial Construct, students introduce and market their new products using digital technology. The ninth item required students to propose a price for their new product, and the tenth item required them to provide three justifications for the suggested price.

There were 60 minutes allocated to answer all the questions. Each item in ECTT has a minimum score of 0 and a maximum score of 3 points. This grading rubric was adapted from Ho et al. (2013). Each score is determined based on the quality of the student's response: Level 1 - 0 points; Level 2 - 1 point; Level 3 - 2 points; and Level 4 - 3 points. The ECT scoring criteria are presented in Table 3. In each construct, students who cannot provide a single answer for each item will receive a score of zero, and so on, until they can provide three correct answers, at which point they will receive a score of three. Table 3 provides an overview of the scoring criteria for the Commercial construct.

Table 3: An Example of the Scoring Rubric according to Students' Response in ECTT

Construct	Ability	Scoring rubric	Levels and Scores
5. Commercial (Introducing and marketing their new products through digital technology)	5.2 Evaluating marketing strategies	3.2.4 Children are able to provide three (3) reasons for choosing a marketing strategy	Level 4 3 marks
		3.2.3 Children are able to give two (2) reasons for choosing a marketing strategy	Level 3 2 marks
		3.2.2 Children are able to provide one (1) reason for choosing a marketing strategy	Level 2 1 mark

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		3.2.1 Children are not able to give one (1) reason for choosing a marketing strategy	Level 1 0 mark
	5.1 Adjust the selling price of the product	3.1.4 Children are able to state three (3) rationals for product pricing	Level 4 3 marks
		3.1.3 Children are able to state two (2) rationals for product pricing	Level 3 2 marks
		3.1.2 Children are able to state one (1) rationale for product pricing	Level 2 1 mark
		3.1.1 Children are not able to state one (1) rationale for product pricing	Level 1 0 mark

Source: Adapted from Ho et al. (2013)

Data Analysis

The research data were analysed in order to determine the content and construct validity. The researchers used the Content Validation Index (CVI) to determine the value of content validity agreement. CVI provides an average rating for each object evaluated by a professional. A CVI value can be calculated for each item on a scale (I-CVI) and for the scale as a whole (S-CVI). Davis (1992) noted that the typical CVI value for a newly designed instrument is 0.80. Polit et al. (2017) suggested a rating of 0.78 or higher for I-CVI and a minimal S-CVI of 0.80 for the averaging approach for cases requiring content validation by at least three experts.

$$\text{Item Content Validation Index (I-CVI)} = \frac{\text{Total of experts in agreement}}{\text{Total of experts}}$$

$$\text{Scale Content Validation Index/Average (S-CVI/Ave)} = \frac{\text{Total I-CVI for each item on the scale}}{\text{Total of items}}$$

In evaluating construct validity and item reliability, WINSTEPS version 3.73 software was utilised. Before the instrument was used for actual research, the instrument's quality and the accuracy of the data obtained need to be guaranteed. According to Edwards & Alcock (2010), person-fit analysis based on the 'MEASURE', 'MNSQ Outfit,' and 'ZSTD Outfit' values need to be conducted. Nevin et al. (2015) asserted that if the ZSTD Outfit value exceeds 2.0 and the MEASURE value is high, there is a chance that exceptional learners will not attentively answer the easy questions. If the ZSTD Outfit value is greater than 2.0, but the MEASURE value is low, low-ability learners will probably be able to answer the challenging items correctly. In order to increase the validity of the instrument, unsuitable respondents will be eliminated (Lamoureux et al., 2008).

For the analysis of item fit, Boone et al. (2014) and Bond and Fox (2015) proposed three criteria: Outfit Mean Square Values (MNSQ), Outfit Z-Standardised Values (ZSTD), and Point Measure Correlation (PTMEA-CORR). The MNSQ Outfit value informs the researcher about the item's fit in the measurement, whereas the PTMEA-CORR value indicates whether the development of the construct met its objective (Bond & Fox, 2007). In addition, ZSTD informs the researcher whether the data obtained conform to the instrument model (Sumintono & Widiarso, 2015). Any item that fails to meet a criterion in Table 4 must be modified or eliminated in order to enhance the value of item fit.

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Table 4: Fit Indices for Item Fit

Statistics	Fit Indices
Outfit mean square values (MNSQ)	0.50 – 1.50
Outfit z-standardised values (ZSTD)	-2.00 – 2.00
Point Measure Correlation (PTMEA-CORR)	0.40 – 0.85

Source: Boone et al. (2014)

Rasch analysis can also be used to identify item polarity through PTMEA-CORR values. A positive PTMEA-CORR value indicates that the item can measure what it is intended to measure accurately, whereas a negative value indicates the opposite. The researchers also evaluate the unidimensionality of the instruments to ensure that they can effectively measure the construct of entrepreneurial creative thinking (Sumintono & Widiyarso, 2015). Component Analysis provides dimensional criteria based on the 'raw variance explained by measures' (Sumintono & Widiarso, 2015). The acceptable value of 'raw variance explained by measures' should be greater than 20%, is regarded as good if it exceeds 40%, and is regarded as outstanding if it exceeds 60% (Table 5). In the meantime, the value of 'unexplained variance in first contrast' should not exceed 15%.

Table 5: Unidimensionality Based on Raw Variance Values Explained by Measures

Value	Interpretation
≥ 20%	Acceptable
≥ 40%	Good
≥ 60%	Excellent

Source: Sumintono & Widhiarso (2015)

The researcher consulted Sumintono and Widhiarso (2015) for Cronbach's alpha (KR-20), item-person reliability, and separation indices (Table 6). The separation index of individuals was used to categorise students' ability levels. A decent separation index should be greater than 2, where the greater the separation index, the more accurate the classification of individuals. In addition, the item separation index was utilised to validate the item hierarchy. The low item separation index value of 3 indicates that the sample of students was insufficient to corroborate the instrument's difficulty hierarchy. Linacre (2002) insisted that a high separation value indicates a high-quality instrument because it can distinguish between the group of items and respondents.

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Table 6: Reliability Measured via the Rasch Analysis

Statistics	Fit Indices	Interpretation
Cronbach’s alpha (KR-20)	< .5	Low
	< .6	Moderate
	.6 – .7	Good
	.7 – .8	High
	.9 – 1.0	Very High
Item and Person Reliability Index	<.67	Low
	.67 – .80	Sufficient
	.81 – .90	Good
	.91 – .94	Very Good
	>.94	Excellent
Item Separation Index	>3	Good
Person Separation Index	>2	Good

Source: Sumintono & Widhiarso (2015) and Linacre (2002)

Research Results

Content Validity of ECTT Instrument

Content validity indicates the extent to which an item adequately represents the content of a trait that a researcher wants to measure (Creswell & Creswell, 2017). Kline (2005) stated that an expert review is necessary to ensure the construct's accuracy and the clarity of its contents. Mullen (2003) remarked that experts are trained in a specific field. In order to increase the content validity of the ECTT instrument items, four expert panels in the disciplines of entrepreneurship, curriculum, and Science Education participated in the content validity process. The researchers used an item evaluation form adapted from the Malaysian Examinations Board (2013). The panel of experts evaluated the ECTT instrument based on its conformity, precision, clarity, and suitability. The process of enhancing the ECTT instrument was informed by and incorporated by the experts' feedback. The panel of content validation experts is displayed in Table 7.

Table 7: Content Validation Panel for ECTT

Name	Institute	Designation	Expertise
Expert A	University	Professor Dr. (PhD)	Entrepreneurship Education and Program Evaluation
Expert B	University	Senior Lecturer (PhD)	Business and Entrepreneurship Education & TVET
Expert C	University	Senior Lecturer (PhD)	Business Management and Entrepreneurship Education
Expert D	Teachers Training Institute (TTI)	Academic Lecturer of STEM Department (PhD)	Curriculum and Instruction (Science)

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According to Polit et al. (2017), items are retained if the I-CVI value obtained is ≥.78; I-CVI values that are less than .78 need to be modified and refined based on suggestions, comments and discussions with expert groups, while very low I-CVI values are to be considered for removal. Table 8 shows the findings from the expert panel on the content validity of this UECT for each item evaluated. Based on these findings, it was found that only items 1a, 2a, 5a and 5b got an I-CVI value of less than .78, and this implies that these items need to be modified and refined according to the recommendations given by the experts. Other items are to be maintained because they reach an I-CVI value above .78. For the determination of S-CVI/Ave, the content validity obtained for this UECT reached .90. This value not only meets the minimum requirement of .78 for the new instrument but also achieves a high content validity value (Polit et al., 2017).

Table 8: Content Validity Index (CVI) Results of the ECTT Instrument

Item	Expert A	Expert B	Expert C	Expert D	Experts in Agreement	I-CVI	Results
1a	-	/	/	/	3	.75	Modified
1b	/	/	/	/	4	1.00	Accepted
2a	/	/	-	/	3	.75	Modified
2b	/	/	/	/	4	1.00	Accepted
3a	/	/	/	/	4	1.00	Accepted
3b	/	/	/	/	4	1.00	Accepted
4a	/	/	/	/	4	1.00	Accepted
4b	/	/	/	/	4	1.00	Accepted
5a	/	/	-	/	3	.75	Modified
5b	/	/	-	/	3	.75	Modified
Scale Content Validation Index/Average (S-CVI/Ave)						**.90**	

Construct Validity

Person Fit

Person fit is the first criterion to be considered when analysing the validity of the UECT instrument using the Rasch model. According to Boone (2016), the Rasch model can determine the person's fit based on their typical response patterns. Unusual response patterns detected by Rasch analysis suggest that students may be imitating or being negligent when answering the question. (Edwards & Alcock, 2019; Nevin et al., 2015) The criteria for evaluating the suitability of respondents are based on the 'MEASURE', Outfit MNSQ, and Outfit ZSTD' values. Nevin et al. (2015) explained that a high outfit ZSTD value (> 2.0) in conjunction with a high MEASURE value suggests that students with high ability may have inaccurately answered 'easy' items. A high value of Outfit ZSTD (> 2.0) combined with a low value of MEASURE suggests that students with limited ability may have answered the 'difficult' item correctly but not other items accurately. Consequently, the elimination of unsuitable respondents can increase the reliability scale (Van Zile-Tamsen, 2017). Item appropriateness assessment criteria can be used to evaluate the appropriateness of respondents (Sumintono & Widiarso, 2015).

Table 9 displays the respondents who provided the most unsuitable response to the Rasch analysis, which differs from the Rasch model's estimates. The students are ordered by their highest Outfit ZSTD score. Twenty respondents (119, 81, 96, 54, 126, 117, 62, 67, 76, 87, 99,

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166, 28, 168, 29, 32, 57, 94, 150, and 178) reported an Outifit ZSTD value greater than 2.0, as stated in Table 9. The remaining respondents' Outfit ZSTD values fell within the range of -2.0 to +2.0. Twenty respondents were eliminated, leaving 167 respondents out of a total of 187 for the subsequent analysis.

These excluded respondents did not participate in the study's intervention or pre-and post-testing. They are only involved in determining the instrument's validity and reliability. After removing 20 from 187 respondents, the remaining number of respondents is sufficient for Rasch model analyses. This is corroborated by Linacre (2002), who states that the sample size for polytomous data in Rasch analysis must be 10 times the number of items. The analysis of the ECTT's 10 question items requires a minimum sample size of 100 individuals.

Table 9: Misfit Order of the Persons in ECTT Instrument

Person	MNSQ *Outfit* (.50-1.50)	ZSTD *Outfit* (-2.0-2.0)	PTMEA-CORR (.40 - .85)
119	3.71	3.5	0.37
81	3.49	3.2	0.06
96	3.41	3.1	-0.15
54	3.03	3.4	-0.55
126	2.90	3.2	-0.34
117	2.50	2.8	-0.08
62	2.49	2.9	-0.79
67	2.49	2.9	-0.79
76	2.49	2.9	-0.79
87	2.49	2.9	-0.79
99	2.49	2.9	-0.79
166	5.40	2.1	0.57
28	2.36	2.4	-0.16
168	2.32	2.5	0.10
29	2.09	2.2	-0.40
32	2.07	2.1	-0.38
57	1.99	2.1	-0.54
94	0.20	-2.3	0.54
150	0.20	-2.3	0.54
178	0.15	-3.3	0.00

Item Fit

Sumintono and Widhiarso (2015) explained that the adequacy of items could assist researchers in determining whether the items function usually and appropriately for measurement purposes. In addition, the logit produced by Rasch analysis can indicate the respondent's capacity to answer questions based on the question's difficulty (Olsen, 2003). The Outfit MNSQ, Outfit ZSTD, and PTMEA-CORR values are used to analyse item fit (Bond & Fox, 2015; Boone et al., 2014; Waugh, 2012).

Based on the Mean Square outfit (MNSQ), suitable items are valued between 0.50 and 1.50. Boone et al. (2014) determined that the optimal range for item fit is between 0.5 and 1.5. According to Table 10, there are two products outside the range: items 7 and 4. According to Boone et al. (2014) and Aziz et al. (2014), items that do not meet all three criteria and fall

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outside the range are deemed inappropriate. However, if an item fulfils one of the retention criteria, it should be retained (Sumintono & Widiarso, 2015). Table 10 demonstrates that every item satisfies at least one criterion. Consequently, no item elimination is performed on this ECTT instrument.

Table 10: Misfit Order of the Items in ECTT

Item	*Outfit* MNSQ (.50-1.50)	*Outfit* ZSTD (-2.0 - 2.0)	PTMEA-CORR (.40 - .85)	Result
I7	1.35	**2.3**	0.69	retained
I6	1.20	1.5	0.69	retained
I8	0.94	-0.2	0.80	retained
I9	0.95	-0.1	0.75	retained
I10	1.09	0.8	0.79	retained
I5	1.10	0.7	0.77	retained
I3	1.05	0.4	0.74	retained
I1	0.82	-1.6	0.83	retained
I2	0.80	-0.6	0.76	retained
I4	0.66	**-3.3**	0.85	retained

Item Polarity

Analysis of item polarity using the PT-MEASURE CORR value reveals that the ECTT items move in the same direction relative to the construct being measured (Linacre, 2002). A positive value indicates that all employed items are functioning in unison, whereas a negative value indicates that the item must be improved or eliminated. PT-MEASURE CORR. Ranges from a minimum of 0.69 to a maximum of 0.85, as shown in Figure 1 (Bond & Fox, 2015). A positive PT-MEASURE CORR analysis indicates that all elements interpret the target construct in the same direction.

```
TABLE 26.1 Rasch Analysis (Data UPKK) baru 13 bu ZOU910WS.TXTs Jul 18 22:45 2022
INPUT: 167 PERSON  10 ITEM  REPORTED: 167 PERSON  10 ITEM  4 CATS WINSTEPS 3.72.3
--------------------------------------------------------------------------------
PERSON: REAL SEP.: 2.83  REL.: .89 ... ITEM: REAL SEP.: 5.41  REL.: .97

         ITEM STATISTICS:  CORRELATION ORDER

-------------------------------------------------------------------------------------------------
|ENTRY   TOTAL  TOTAL           MODEL|   INFIT  |  OUTFIT  |PT-MEASURE |EXACT MATCH|        |
|NUMBER  SCORE  COUNT  MEASURE  S.E. |MNSQ  ZSTD|MNSQ  ZSTD|CORR.  EXP.| OBS%  EXP%| ITEM   |
|------------------------------------+----------+----------+-----------+-----------+--------|
|     6    358    167      .36   .17|1.14   1.3|1.20   1.5|  .69   .78| 71.4  70.7| Item 6 |
|     7    365    167      .16   .17|1.04    .4|1.35   2.3|  .69   .77| 76.4  71.9| Item 7 |
|     3    364    167      .19   .17|1.08    .7|1.05    .4|  .74   .77| 78.3  71.7| Item 3 |
|     9    404    167    -1.10   .19|1.12    .9| .95   -.1|  .75   .75| 70.2  77.7| Item 9 |
|     2    421    167    -1.74   .20| .73  -2.1| .80   -.6|  .76   .72| 84.5  79.7| Item 2 |
|     5    380    167     -.30   .18|1.05    .5|1.10    .7|  .77   .77| 72.0  73.8| Item 5 |
|    10    338    167      .92   .17|1.10    .9|1.09    .8|  .79   .78| 60.9  69.2| Item 10|
|     8    402    167    -1.03   .19|1.17   1.3| .94   -.2|  .80   .75| 71.4  77.5| Item 8 |
|     1    342    167      .81   .17| .84  -1.6| .82  -1.6|  .83   .78| 65.2  69.4| Item 1 |
|     4    308    167     1.72   .16| .67  -3.4| .66  -3.3|  .85   .79| 83.9  69.0| Item 4 |
|------------------------------------+----------+----------+-----------+-----------+--------|
| MEAN   368.2  167.0      .00   .18| .99   -.1| .99    .0|           | 73.4  73.1|        |
| S.D.    32.7     .0     1.00   .01| .17   1.6| .19   1.5|           |  7.1   3.7|        |
-------------------------------------------------------------------------------------------------
```

Figure 1: Item Polarity Analysis

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Unidimensionality

In addition to the appropriateness of items and respondents, it is crucial for researchers to evaluate the validity of an instrument to ensure that it measures what it is intended to measure (Aziz et al., 2014; Sumintono & Widhiarso, 2015). According to Ariffin et al. (2010), the developed items should evaluate constructs that measure a single dimension. Rasch analysis utilising Principal Component Analysis evaluates the accuracy with which an instrument measures what it is intended to measure. Sumintono and Widhiarso (2015) provide criteria for unidimensionality based on the total variance explained by measures in Principal Component Analysis. Raw values explained by measurements exceeding 20% are acceptable, exceeding 40% is fine, and exceeding 60% is excellent. In the meantime, the optimal measurement value for the raw value should not exceed 15%.

Unidimensionality is essential to ensure that the devised instrument can measure in a single direction and that the study's results are not misleading. According to Figure 2, the raw variance explained by measures is 61.9%, which is close to the 61.6% predicted by the Rasch model. According to Sumintono and Widhiarso (2015), a value that exceeds 60% is 'high', indicating that the instrument has significant evidence of unidimensionality, i.e., this instrument accurately measures the construct. In addition, the value of 'unexplained variance' between the first and fifth contrasts is less than 8%, which lies within the ideal range of less than 15%.

```
TABLE 23.0 Rasch Analysis (Data UPKK) baru 13 bu ZOU910WS.TXTs Jul 18 22:45 2022
INPUT: 167 PERSON  10 ITEM  REPORTED: 167 PERSON  10 ITEM  4 CATS WINSTEPS 3.72.3
--------------------------------------------------------------------------------

     Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)
                                           -- Empirical --    Modeled
Total raw variance in observations     =       26.2 100.0%         100.0%
  Raw variance explained by measures   =       16.2  61.9%          61.6%
    Raw variance explained by persons  =       11.5  43.9%          43.7%
    Raw Variance explained by items    =        4.7  18.0%          17.9%
  Raw unexplained variance (total)     =       10.0  38.1% 100.0%   38.4%
    Unexplned variance in 1st contrast =        2.0   7.8%  20.5%
    Unexplned variance in 2nd contrast =        1.7   6.4%  16.7%
    Unexplned variance in 3rd contrast =        1.5   5.7%  15.0%
    Unexplned variance in 4th contrast =        1.2   4.5%  11.7%
    Unexplned variance in 5th contrast =         .8   3.2%   8.5%
```

Figure 2: Principal Component Analysis of Rasch Residual (PCAR)

Reliability and Separation Indices

Sumintono and Widhiarso (2015) stated that there are two appropriate index criteria (Table 12) to demonstrate the Rasch model's reliability, namely i) item and respondent reliability and ii) item and respondent separation. Linacre (2003) states that, for the division of items and respondents, a separation value greater than 2 is adequate.

Figure 3 and Table 11 display the item-response reliability and item-response separation values for the ECTT instrument based on Rasch analysis. The respondent reliability value is .89, and the separation value is 2.83. Sumintono and Widhiarso (2015) stated that a respondent reliability value greater than 0.80 is regarded as 'good,' whereas Bond and Fox (2007) indicated that a respondent reliability value greater than 0.80 indicates that the respondent's response is good and consistent. For the person separation value, a value of 2.83 is interpreted as 'good', as supported by Linacre (2003), who stated that a good separation value for item difficulty is appropriate if the respondent's separation value is greater than 2.00. In the meantime, Krishnan

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and Idris (2015) affirmed that the respondent separation value must be greater than 1.00 for students to be measured across the dispersion.

In addition, the Rasch analysis revealed that the item reliability value is 0.97, and the item separation value is 5.41. Sumintono and Widhiarso (2015) defined 'high' item reliability as exceeding 0.94. Bond and Fox (2007) indicated that item reliability values above 0.80 have excellent and widely accepted values, whereas values below 0.80 are less widely accepted. A value of 5.41 for the item separation value is considered acceptable and satisfies the requirements (Linacre, 2003). Linacre (2003) stated that item separation values greater than 2.00 are acceptable. In the meantime, Krishnan and Idris (2014) stated that item separation values greater than 1.00 indicate adequate dispersion.

```
     SUMMARY OF 167 MEASURED PERSON
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT     |
|          SCORE      COUNT     MEASURE  ERROR      MNSQ   ZSTD   MNSQ   ZSTD  |
|------------------------------------------------------------------------------|
| MEAN      22.0       10.0        3.07    .77                                 |
| S.D.       5.4         .0        2.62    .26                                 |
| MAX.      30.0       10.0        8.03   1.87                                 |
| MIN.       2.0       10.0       -5.58    .62        .35   -2.0    .30   -1.9 |
|------------------------------------------------------------------------------|
| REAL RMSE    .87 TRUE SD     2.47  SEPARATION  2.83  PERSON RELIABILITY  .89 |
|MODEL RMSE    .82 TRUE SD     2.49  SEPARATION  3.05  PERSON RELIABILITY  .90 |
| S.E. OF PERSON MEAN = .20                                                    |
-------------------------------------------------------------------------------
PERSON RAW SCORE-TO-MEASURE CORRELATION = .99
CRONBACH ALPHA (KR-20) PERSON RAW SCORE "TEST" RELIABILITY = .92

     SUMMARY OF 10 MEASURED ITEM
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT     |
|          SCORE      COUNT     MEASURE  ERROR      MNSQ   ZSTD   MNSQ   ZSTD  |
|------------------------------------------------------------------------------|
| MEAN     368.2      167.0         .00    .18        .99    -.1    .99     .0 |
| S.D.      32.7         .0        1.00    .01        .17    1.6    .19    1.5 |
| MAX.     421.0      167.0        1.72    .20       1.17    1.3   1.35    2.3 |
| MIN.     308.0      167.0       -1.74    .16        .67   -3.4    .66   -3.3 |
|------------------------------------------------------------------------------|
| REAL RMSE    .18 TRUE SD      .99  SEPARATION  5.41  ITEM   RELIABILITY  .97 |
|MODEL RMSE    .18 TRUE SD      .99  SEPARATION  5.60  ITEM   RELIABILITY  .97 |
| S.E. OF ITEM MEAN = .33                                                      |
-------------------------------------------------------------------------------
```

Figure 3: Reliability Analysis and Separation Index

Table 11: Summary of the Item-Person Reliability and Separation Findings

	Rasch Measurement	ECTT	Interpretation
Cronbach's alpha (KR-20)	.9 – 1.0	.92	Very high
Item Reliability	>.94	.97	High
Item Separation Index	> 3.0	5.41	Good
Person Reliability	.81 – .90	.89	Good
Person Separation Index	> 2.0	2.83	Good

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Discussion

The Rasch Measurement Model was used to assess the validity and reliability of ECTT. The content validity analysis revealed that all ECTT items are admissible except for items 1a, 2a, 5a, and 5b. S-CVI/Ave analysis indicated that the instrument has a high content validity value of .90. The item fit analysis indicated that all items are acceptable because items met at least one of the criteria in Outfit MNSQ, Outfit ZSTD, and PTMEA-CORR. All items have been found to have a positive PT-MEASURE CORR value, indicating that they all progress in the same direction with respect to the five constructs being measured (Linacre, 2002). A positive value indicates that all items operate in an acceptable and parallel manner. The unidimensionality analysis conducted on the ECTT items revealed a value greater than 60%, which is 'high' and indicates that this instrument accurately measures the constructs of ECTT (Sumintono & Widhiarso, 2015). The item reliability analysis revealed that the items in the ECTT instrument recorded a value of .97 with a value of 5.50 for item separation. This high-reliability value indicates that the ECTT items are suitable for use in actual field investigations (Bond & Fox, 2007; Sumintono & Widhiarso, 2015). Likewise, the respondent reliability demonstrated that the ECTT items are appropriate for Form Four students in high schools. Thus, the Rasch analysis demonstrates that the ECTT instrument is ideally suited for use in actual field research.

Five constructs, namely Investigation, New Ideas, Design, Create and Commercial, were established as the focus of the ECTT instrument. All ten open-ended items went through the content validation phase by four experts. The construct validity analysis was conducted for item and person fit, item polarity as well as unidimensionality. Van Zile-Tamsen (2017) highlighted the importance of empirically evaluating the psychometric properties and integrity of rating scales. The quality of rating scales and items can be concluded by employing a systematic procedure to collect and analyse data and compare results against specific, predetermined criteria. The results of Rasch's analysis show that ECTT has good psychometric quality. A positive PTMEA-CORR analysis indicates that all items move in the same direction in measuring the constructs to be measured (Bond & Fox, 2015; Linacre, 2012). Meanwhile, the obtained Raw Variance Explained by the Measures value of the ECTT instrument proved that the ECTT instrument truly measures the five constructs of entrepreneurial creative thinking. In other words, there were no extra constructs found in ECTT (Aziz et al., 2015; Fisher, 2007).

The ECTT instrument was also tested for its reliability and separation index. According to Cohen and Swedlik (2018), a good set of test items can be distinguished by respondents. The ECTT instrument was found to have a very high Cronbach's alpha value, excellent item reliability value and good person reliability. These findings show that the reliability of the ECTT instrument is high in assessing the entrepreneurial creative thinking of high school students in STEM education. The obtained good item separation value shows that the ECTT instrument can be categorised into five strata of item levels, while the obtained person separation value proves that Form Four students can be divided into three strata according to ability level, that is, Excellent, Average and Poor.

Most instruments developed by previous researchers (Ahmad & Siew, 2021; Al Mamun et al., 2018; Block et al., 2013; Bolton & Lane, 2012; Ishak et al., 2014; Sahban et al., 2015; Schelfhout et al., 2016) concentrate on students' level of entrepreneurial thinking in the field of engineering, entrepreneurship education and entrepreneurial science thinking. This

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limitation was addressed with the development of ECTT by including the commercialisation aspects of entrepreneurial thinking. This study showed that ECTT utilises an open-ended questions approach that is feasible for students to offer their views about market value based on their experience and knowledge in STEM education (LiñáN & Chen, 2009). In addition, most previous entrepreneurial thinking instruments used the exploratory factor analysis method, while ECTT uses Rasch analysis, which leads to the instrument's accuracy.

Conclusions and Future Research

The Entrepreneurial Creative Thinking Test fills the gap left by lacking an instrument that can accurately measure entrepreneurial creative thinking through five constructs: investigation, new idea, design, create, and commercial. This instrument could assist teachers in planning efforts to implement elements of commercial aspects of entrepreneurial creative thinking for high school students in STEM education.

The study of the development of entrepreneurial creative thinking tests also demonstrated the capability of the Rasch Measurement Model to serve as a model in carefully and precisely determining the validity and reliability of a newly developed instrument. In fact, this finding supports other researchers that Rasch analyses of the ECTT instrument can be conducted for students in other fields. In conclusion, the analysis of validity and reliability using the Rasch Measurement Model demonstrated that the ECTT instrument is valid and reliable for measuring the entrepreneurial creative thinking of Form Four students in rural high schools.

Even though the findings suggest that ECTT is a reliable and valid instrument for STEM education, its limitations should be acknowledged. ECTT was tested in four schools using a sample of 187 students; it may not represent the general population of rural high school students. Future research needs to involve a bigger sample size. ECTT can be infused into any STEM curriculum integrated model to promote entrepreneurial creative thinking in STEM. It is suggested to extend the usage of the ECTT instrument to other regions of the country, as well as to a variety of learners for greater generalisability.

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