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DEVELOPMENT OF A CHILDREN ENTREPRENEURIAL SCIENCE THINKING TEST FOR STEM EDUCATION

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Abstract. *There are limited research studies about the development of test instrument to assess the level of entrepreneurial thinking among children in STEM education. The purpose of this research was to develop an Entrepreneurial Science Thinking Test (ESTT) for primary school children in STEM Education and evaluate its validity and reliability. The ESTT was developed using experiential learning theory which comprised of five constructs, namely Observation, New Ideas, Innovation, Creativity, and Value. The ESTT consisted of ten open-ended question items that require children to answer questions in statements and draw sketches of ideas. The evaluation was conducted to determine the reliability and validity of ESTT which involved five subject matter experts and 166 11-year-old fifth graders from five urban schools in Sabah, Malaysia. The data obtained from fifth graders were computed using WINSTEPS software version 3.73 and analysed using the Rasch measurement model. The results indicated a high acceptable content validity and construct validity, high internal consistency, and excellent item reliability and item separation. Through item fit analysis, all items were retained. The finding established the reliability and validity of the ESTT and would therefore represent a valid and highly reliable instrument for measuring entrepreneurial science thinking among fifth graders in STEM Education.*

Keywords: *experiential learning theory, science entrepreneurial thinking, validity and reliability, STEM education*

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Introduction

Entrepreneurial thinking (ET) is one of many critical skills that 21st century learners require in facing an increasingly competitive world. ET has the potential to enrich human capital in gaining innovative knowledge, new revolutionary ideas, and strong ethical standards (Bacigalupo et al., 2016). ET can be defined as a cognitive situation that seeks creative and innovative ideas as well as opportunities (Krueger, 2005). ET is not an ability that needs to be mastered in order to become a mere entrepreneur, but it is a soft skill that is required to enhance human growth, meet the job market and improve productivity (Bacigalupo et al., 2016). In producing learners who can master the characteristics and ethics of entrepreneurship, handle existing resources well and face future challenges efficiently, this ET is very important (Edwards-Schachter et al., 2015). Learners can be more analytical, creative, and inventive thinkers, successful in communication, and ethical workers with these skills (Lekashvili, 2013).

The importance of ET for supplying skilled workers who can communicate different soft skills in Science, Technology, Engineering and Mathematics (STEM) fields has been acknowledged by some countries in their 21st century curricula (Borowczak, 2015). However, integrating ET is still not widespread in STEM education. Eltanahy et al. (2020) stressed the importance of applying ET in STEM learning to raise the awareness of STEM design among learners and inspire them to be more entrepreneurial. Learners studying STEM without ET skills are less likely to have the capability to determine the value of products derived from the socio-economic aspects of society. This is significant because learners are currently showing high trends (61.4%) towards STEM-based careers (Hatisaru, 2021). Swartz and McGuinness (2014) stressed that thinking skills need to be explicitly taught in curricula, while Gunawan & Shieh (2020) recommended that ET is integrated into any STEM curriculum to produce a significant effect on learning.

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Realizing the need for entrepreneurial thinking in STEM, the importance of ET began to be examined by some Malaysian local scholars. Buang et al. (2009) have proposed a combination of science process skills and entrepreneurial thinking known as Entrepreneurial Science Thinking (EST). This concept integrates problem-solving ideas and entrepreneurial elements to train learners to search for thorough ideas in solving a problem creatively (Syukri et al., 2013b). However, there is little research on the development of test instruments to assess the level of entrepreneurial science thinking among primary school children in STEM education. It is therefore important to develop an ET test for STEM education to ensure that ET is nurtured in STEM education from primary school level (Liu & Zhi, 2010; Menzies, 2012; Sheehan et al., 2018). The Entrepreneurship Science Thinking Test (ESTT) was developed in line with this to assess entrepreneurial science thinking among fifth graders in STEM education.

Research Problem

Entrepreneurial science thinking begins with an important basic science skill which is the skill of creating (Daniel, 2016; Neck & Greene, 2011). In the concept of classroom assessment in Malaysian schools, learners with good creating skills can achieve the mastery level six (ML6). However, based on the Classroom Assessment Mastery Achievement Report (Tawau District Education Office, 2019), the number of tenth graders who achieved ML6 for Science subjects was only 4%, far behind when compared to ML5 (23.82%) and ML4 (44.25%).

Furthermore, based on the PISA Report 2018 (Schleicher, 2019), the average score of Malaysian ninth graders in terms of science literacy is only 438, below the international average score of 489. This is a disconcerting scenario because the nation holds high aspirations to achieve a nation of creators by 2030. Therefore, it is obvious that entrepreneurial science thinking needs to be infused from the primary school level to better develop the children's science literacy, critical thinking, and reasoning skills (Hoachlander & Yanofsky, 2011; National Research Council, 2011).

The application of entrepreneurial science thinking in STEM Education is now considered significant in preparing children today to venture into STEM-related careers (Dabney et al., 2012; Sadler et al., 2012; Wyss et al., 2012). Such application will encourage children to solve challenging and meaningful daily problems as well as improve their cognitive reasoning skills (Hunter et al., 2016). In addition, entrepreneurial science thinking opens up space for learners to think more broadly to explore new ideas in STEM-based problems (English et al., 2017). Children with entrepreneurial science thinking are able to learn STEM in real context and develop their STEM literacy in order to succeed in the modern economic era (Tsupros et al., 2009). In fact, they are also able to face the challenges of daily life related to the field of STEM (Bybee, 2013). In addition, entrepreneurial science thinking also encourages children to improve Science literacy (McDonald, 2016) and engineering design skills emphasized in STEM (Afriana et al., 2016; Jin & Bierma, 2013; Kennedy & Odell, 2014; Kuenzi, 2011; Zollman, 2012). It is clear that the application of entrepreneurial science thinking in STEM Education needs to be implemented explicitly starting at a lower school level to achieve the country's desire to produce STEM-skilled human capital capable of solving global problems, making decisions, and innovating creations for the benefit of future societies.

Although entrepreneurial thinking has been introduced in the Malaysian curriculum, the development of instruments that measure the level of entrepreneurial science thinking among primary school children in STEM education is not yet widespread (Buang et al., 2009; Syukri et al., 2013a). Instruments that have been developed previously only measure the readiness of the integration of entrepreneurial science thinking (Ishak et al., 2014) and teacher pedagogical knowledge in teaching entrepreneurial science thinking (Syukri et al., 2013b).

Li et al. (2016) developed an instrument for measuring entrepreneurial thinking among engineering students. The instrument was developed based on Kern Entrepreneurial Engineering Network (KEEN) framework that is specialised in the context of 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' creation. Bolton and Lane (2012) developed an Individual Entrepreneurial Orientation (IEO) instrument for testing entrepreneurial thinking among 1,100 university students. By using exploratory factor analysis, the instrument was found reliable and valid in assessing three of the five dimensions: innovativeness, risk-taking, and proactiveness. However, the measurements are comparatively restricted in these three dimensions. The extent to which the students' observation of current materials and

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designs, as well as the contribution of inventions to society, was not assessed. Schelfhout et al. (2016) constructed an instrument to assess entrepreneurial competence using a behavioural indicator scale, in addition to measuring entrepreneurial thinking. The instrument was developed with 11 sub-competencies that assess high school students' competence and entrepreneurial thinking.

To sum up, most instruments constructed for measuring entrepreneurial thinking are appropriate for learners of higher education and secondary school. There are few and limited instruments targeting entrepreneurial science thinking for primary school children in STEM education. Hence, an instrument for assessing entrepreneurial science thinking for STEM Education needs to be developed and introduced at a lower school level. In line with this, the Entrepreneurship Science Thinking Test (ESTT) was developed, and its validity and reliability were assessed to ensure its usability in measuring entrepreneurial science thinking among fifth graders in STEM education.

Literature Review

Science Entrepreneurial Thinking

The concept of Entrepreneurial Science Thinking (EST) is a notion of science teaching and learning to produce learners who are equipped with entrepreneurial thinking (Syukri et al., 2013a). EST is referred to as design thinking skills based on scientific knowledge and entrepreneurial orientation (Buang et al., 2009). Buang et al. (2009) proposed the Entrepreneurial Science Thinking Model (ESTM) which provided the theoretical model of entrepreneurial thinking in this study. ESTM consisted of five constructs namely Observation, New Ideas, Innovation, Creativity, and Value as described below.

Observation

The observation construct refers to the activity of observing various phenomena found in the environment that is related to the concept of science (Buang et al., 2009). The observation construct, as described in this study, is the activity of making observations in a planned and purposeful manner. Learners make observations about the appropriate materials and designs used to make a new product.

New Ideas

There is a need for new ideas through phenomena that have been observed in the form of ideas, systems, models, designs, or products (Buang et al., 2009). In this research, the new ideas construct suggests that learners generate ideas by continuously thinking about the use of materials and the design of materials used in new products to seek uniqueness.

Innovation

Buang et al. (2009) stressed that the innovation construct refers to the activity of learners selecting some ideas that can be improved and evaluating the selected ideas. In this research, the innovation construct allows students to select ideas that can be modified or improved from the previous steps. In the future, the selection of these ideas for change helps in creating product designs. Learners then need to evaluate the ideas by specifying the reasons for the idea they selected.

Creativity

The definition of creativity can be applied in a concentrated way as the task of creating new ideas (Buang et al., 2009). In this study, the creativity construct refers to the task of reinforcing and evolving ideas in a concentrated way. Learners express their new ideas by sketching designs, labelling, and building product design models. Learners are then asked to state the name of the product, the price offered and the target group of buyers for the product produced.

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Value

Value constructs refer to activities to ensure that the ideas or products produced are beneficial to society. In terms of cost savings, product function as well as values and ethics in product invention, learners need to state the benefits of their products. This is to cultivate values such as love of the environment and the practice of using sustainable materials in the production of products for the community. Learners then present their model in front of the class and present the benefits of their products.

Experiential Learning Theory in ESTT Development

Kolb (1984)'s experiential learning theory defines learning as "the process whereby knowledge is created through the transformation of experience" (p. 41). Kolb proposed that learners learn through a circle of experiences that lead to observations and reflections. These reflections are applied to prior understanding and converted into abstract concepts or theories, resulting in forms and behaviours to adapt to new experiences that can be tested and explored. As claimed by Gemmell and Kolb (2013), experiential learning theory is in line with the concept of entrepreneurial science thinking which is based on learning through reflection and experience. Entrepreneurial science thinking needs to go through social and cognitive processes where learners develop new ideas and transform those ideas so that they can be used in the market and society (Gemmell et al., 2012). Thus, this theory provided the theoretical framework of ESTT development where learners use their experience to solve consumer problems and produce innovative products and services for the benefit of society.

Kolb (1984) further reiterated that individuals progress through the four stages of the learning cycle that are interconnected, namely concrete experience, reflective observation, abstract conception, and active experimentation (Figure 1). During the stage of concrete experience, learners are involved with new experiences which become the basis of observation. Next, in reflective observation, individuals reflect on their observation and begin to construct a general theory of what this information means. In the next step of abstract conceptualization, learners organize information systematically and logically into concepts, theories, and ideas. Finally, during the active experimentation stage, learners test the implications of these concepts in new situations. At this stage, learners are able to see things from various perspectives and act creatively and innovatively. The process once again returns to the first stage of the experience process.

The learning process of Kolb (1984)'s theory is in line with ESTT development, which encourages learners to experience the phases of Observation, New Ideas, Innovation, Creativity, and Values. Learners were exposed to issues through concrete experiences that would lead to the emergence of various ideas, which is in line with Observation in ESTT. This process leads to reflective thinking where learners obtain ideas and inspiration to invent products that could help in problem-solving. Hence, the reflective thinking stage is in line with New Ideas in ESTT. In the abstract conceptual stage, learners began to organize ideas and translate ideas in the form of prototype sketches. This is where innovation and creativity in ESTT take place. At this stage, through the experience they went through, learners invent their prototype. Carlsson et al. (1976) explained that the process of implementing solutions to issues would be carried out during the stage of active experimentation. Accordingly, learners evaluated their products by ensuring that the products invented could solve issues and benefit the users. As explained by Krakauer et al. (2017), the stage of active experimentation is the stage where learners relate their perceptions to the actual context. In this study, the actual context refers to the context of society where learners applied their STEM knowledge and experience in inventing the products that would benefit society. This stage represents the Value construct of ESTT.

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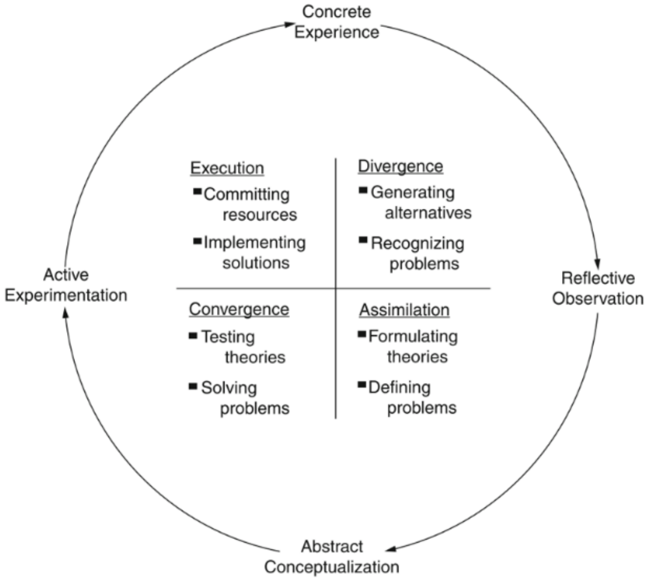
Figure 1
Learning cycle in Kolb's Experiential Learning Theory (1984)



Rasch Measurement Model

The Rasch Measurement Model (RMM) is an efficient solution for the development of in-depth statistics to provide high validity and reliability of ESTT instrument (Bond & Fox, 2015). RMM analyses each respondent's ability to respond to the instrument and measures the difficulty of each item in the instrument (Wolins et al., 1982). RMM is also able to assess latent characteristics, such as human thoughts and emotions (Aziz et al., 2015).

The RMM built on the basis of Item Response Theory is among the adequate statistical models as it can calculate the item's difficulty and the individual's ability to be evaluated at the same time (Deane et al., 2016). As a result, the RMM was able to classify the items and person validity and reliability. Furthermore, Rasch analysis can be used in terms of item polarity, item and respondent misfit, as well as dimensionality, to perform construct validity.

While Rasch analysis can take a longer process than conventional analysis, Rasch analysis may offer a deeper understanding of the instrument's strengths and shortcomings (Boone & Scantlebury, 2005). Bond and Fox (2007) claimed that RMM, by statistical analysis, is an efficient solution for developing highly valid and reliable instruments. The researchers used Rasch analysis to assess the validity and reliability of the ESTT instrument based on these specified strengths.

Research Focus

The main focus of this research was to develop an instrument on entrepreneurial science thinking in STEM Education for 11-year-old children in primary schools. Validity and reliability are two important factors to consider when developing an instrument. Hence for the need to develop a valid and reliable tool, Rasch analysis was used to examine the validity and reliability of ESTT.

Research Aim and Questions

This research was aimed to develop a valid and reliable instrument for assessing entrepreneurial science thinking in STEM Education among fifth graders using the Rasch Measurement Model. There were three research questions guiding this research:

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Q1: Is ESTT feasible in assessing entrepreneurial science thinking among fifth graders in STEM Education?

Q2: How valid is ESTT in assessing fifth graders' science entrepreneurial thinking in STEM Education based on: 1) Person fit statistics; 2) Item fit statistics; 3) Item Polarity; and 4) Confirmation of unidimensionality?

Q3: How reliable is ESTT in assessing the entrepreneurial science thinking in STEM Education among fifth graders according to: 1) KR-20 Cronbach's coefficient alpha; 2) Person and item reliability indices?

Research Methodology

Research Design

A survey design using a test instrument was employed to obtain data on fifth graders' entrepreneurship thinking level. In education, a survey research design is well established as it can analyse topics and constructs efficiently and economically (Creswell & Creswell, 2017). The data gathered from the ESTT instrument was focused on the fifth graders' experiences of integrating the entrepreneurship elements in science project-based learning. This research was carried out between November and December 2019.

Research Sample

The ESTT was distributed to 166 samples that were chosen randomly from five primary schools in the Tawau district, Sabah, Malaysia. A sample size with the range of 108-243 is wide enough to have 99% confidence that the item difficulty can be measured within ± 1⁄2 logit of its stable value (Linacre, 1994). The research sample had a similar background where the selected schools were grouped in urban school clusters. The sample consisted of 87 girls (52.4%) and 79 boys (47.6%) aged between 10 to 11 years. Approximately 60% of parents were government employees, while 40% were working in the private and industry sectors.

Ethical Considerations

Written consent was obtained from the parents and school principals prior to the administration of ESTT. Initially, an outline of the intent of the ESTT which was to measure the level of entrepreneurial science thinking was meted out. The consent letter detailed the fifth graders' involvement in the research and the parents' consent reflecting their understanding of the research purpose. All the fifth graders were assured of the confidentiality of their responses and complete anonymity. Fifth graders were also informed that anyone could withdraw from the research without penalty. A follow-up briefing session was then carried out to explain the guidelines and procedures for answering questions in ESTT.

Administration of ESTT

Each fifth grader was asked to read the instructions carefully before answering the ESTT according to their respective knowledge without the help of other children. Fifth graders relate current information, insights, and experiences to the scientific principles and entrepreneurial aspects surrounding them throughout answering questions, such as building materials, the use of construction materials, design, uniqueness of an invention, and the impact of an invention on society. Fifth graders were given an hour to think and articulate their responses. Open questions were given according to the construct and fifth graders were required to answer the questions in the order of the constructs. The answers were collected and reviewed in advance to ensure the fifth graders followed the correct instructions and provided complete answers before the data are analysed using WINSTEPS software version 3.73.

Instrumentation

Entrepreneurial science thinking is the ability to create and make improvements to a product, idea, or process so that the product has added value from the social and economic aspects. In this regard, the relationship of sci-

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ence concepts acquired in the classroom and the ability of teachers in nurturing EST triggers innovation to adapt to situations that occur and are needed in the daily life of children (Venuvinod & Sun, 2002). This concept was used when developing the question items in the Entrepreneurial Science Thinking Test (ESTT).

Open-ended questions were used in measuring the entrepreneurial science thinking of each individual. 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 in EST (Buang et al., 2009) which are Observation, New Ideas, Innovation, Creativity, and Value.

The ESTT consisted of ten open-ended question items that require fifth graders to answer questions in statements and draw sketches of ideas. Question items were developed by referring to the content of Standard Documents of Curriculum and Assessment (DSKP) for Year Five Science under the themes of Physical Science as well as Technology and Sustainable Life (Curriculum Development Division, 2019, p. 55-68). The main question asked fifth graders to produce cell phone designs for the use of the future community. The context of cell phone usage was chosen because it is one of the criteria in DSKP under the theme of Physical Science. Fifth graders were then given a stimulus picture and ten question items. Items were arranged according to the group of constructs to enable fifth graders to organize their answers which then lead them to Entrepreneurial Science Thinking. Table 1 shows the constructs of the Entrepreneurial Science Thinking Test (ESTT) for STEM Education.

Table 1
Items for ESTT by Construct

Construct	Definition	Item No.	Item statement
Observation	Make observations in a planned and purposeful manner.	1a	State the materials used to make cell phones.
		1b	State the design of a cell phone that you can observe.
New Ideas	Generate ideas by looking for uniqueness	2a	Explain the advantages of using the materials you mentioned to build the cell phone.
		2b	Explain the advantages of using the cell phone design you mentioned.
Innovation	Select ideas that can be improved and evaluate those ideas	3a	Based on the ideas you have stated in question 2, select three (3) ideas that you can improve to produce future cell phones.
		3b	Why did you choose the above ideas? Give three (3) reasons.
Creativity	Strengthen and improve ideas in a focused way	4a	Reinforce and improve the three (3) ideas you have chosen for the creation of new cell phones for future community use. Sketch and label new features on your model in the space provided.
		4b	Complete details about your product by stating the product name, price offered and target group of buyers.
Value	Ensure that the ideas or products produced are beneficial to the community	5a	State the benefits of your product to the community in terms of cost savings and product functionality.
		5b	State the benefits of your product to the community in terms of values and ethics in product creation.

Children were required to make observations in a prepared and purposeful way in the Observation Construct. The first item required the children to state the materials used to make a cell phone, whilst the second item required the children to state the cell phone design. Children were required to produce ideas relevant to individuality in the creation of New Ideas. By specifying the benefits of utilising the products and design requirements in the observation stage, children had to search for uniqueness or benefits. The fifth item in the Innovation Construct instructed children to choose three ideas that could be augmented and updated in order to create potential cell phones, while the sixth item requested children to state the reasons for choosing the ideas mentioned. The Creativity Construct allows children to validate and strengthen concepts in a focused way. The seventh item centred on children strengthening and improving the concepts chosen for the development of new cell phones. They were requested in this item to draw and mark new features on the model they made. Next by specifying the name of the product, the price available, and the target category of purchasers, the eighth item advised children to complete the details of the product they had made. Finally, the Value Construct was where children wanted to ensure that

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the products would help the society. The ninth and tenth items allowed children to state the advantages in terms of cost savings and include terms of values and ethics in product development, respectively.

The time allocation for answering all the items was 60 minutes. The scoring rubric for the Entrepreneurial Science Thinking Test construct was adapted from Ho et al. (2013). There is a minimum score of 0 and a maximum score of three for each item given in the test. Based on the child's response, each score was rated from 0 to 3 points. An example of a scoring rubric according to children's response for one of the constructs in ESTT is shown in Table 2.

Table 2
An Example of the Scoring Rubric according to Children' Response in ESTT

Construct	Ability	Scoring rubric	Levels and Scores
3. Innovation (Select ideas that can be improved and evaluate those ideas)	3.2 Make an evaluation of the ideas that have been selected.	3.2.4 Children can provide three (3) factors in the selection of ideas.	Level 4 3 marks
		3.2.3 Children can give two (2) factors in the selection of ideas.	Level 3 2 marks
		3.2.2 Children can provide one (1) factor in the selection of ideas.	Level 2 1 mark
		3.2.1 Children cannot give one (1) factor in the selection of ideas.	Level 1 0 mark
	3.1 Choose ideas that can be improved to produce new inventions.	3.1.4 Children can choose three (3) ideas	Level 4 3 marks
		3.1.3 Children can choose two (2) ideas	Level 3 2 marks
		3.1.2 Children can choose one (1) idea	Level 2 1 mark
		3.1.1 Children cannot choose one (1) idea	Level 1 0 mark

Source: Ho et al. (2013)

Data Analysis

The data of the research were analysed to determine the content and construct validity. To determine the value of content validity agreement, the researchers used the Content Validation Index (CVI). CVI provides an average rating of scores for all items evaluated by an expert. A CVI value can be computed for each item on a scale (I-CVI) as well as for the overall scale (S-CVI). Davis (1992) pointed out that for a newly designed instrument, the usual CVI value obtained is .80. For cases with content validation requiring three or more experts, Polit et al. (2017) recommended a rating of .78 and above for I-CVI and a minimum S-CVI of .80 for the averaging approach.

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

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

For assessing construct validity and item reliability, WINSTEPS software version 3.73 was used. This ensured the instrument's quality and the accuracy of the data obtained by the researcher before the instrument was used in actual research. The first analysis was conducted via a person fit analysis which was based on the values of 'MEASURE', MNSQ Outfit and ZSTD Outfit (Edwards & Alcock, 2010). Nevin et al. (2015) asserted that if the ZSTD Outfit value exceeds 2.0 and the MEASURE value is high, there is a probability that excellent learners would not carefully answer the easy items. If the ZSTD Outfit value exceeds 2.0 but the MEASURE value is low, it is likely that

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low-ability learners would be able to answer difficult items correctly. Therefore, unfit respondents will be eliminated to increase the validity of the instrument (Lamoureux et al. 2008).

For the item fit analysis, Boone et al. (2014) as well as Bond and Fox (2015) proposed three criteria namely, 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 fit in the measurement while the PTMEA-CORR value indicates whether the development of the construct has achieved its goal (Bond & Fox, 2007). In another aspect, ZSTD provides information to the researcher whether the data obtained really conforms to the instrument model. Any item that fails to meet one of the criteria in Table 3 needs to be modified or dropped so that the item fit value can be increased (Sumintono & Widhiarso, 2015).

Table 3
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 accurately measure what it needs to measure and vice versa if its value is negative. The researchers also assess the instruments' unidimensionality to guarantee that the instrument can successfully measure the construct of entrepreneurial science thinking (Sumintono & Widhiarso, 2015). Component Analysis provides dimensional criteria based on the 'raw variance explained by measures' (Sumintono & Widhiarso, 2015). The accepted value of 'raw variance explained by measures' should exceed 20%, is considered good if it is more than 40% and considered excellent if more than 60%. Meanwhile, the value of 'unexplained variance in first contrast' should not exceed 15%.

In terms of reliability, the researcher referred to Sumintono and Widhiarso (2015) for Cronbach's alpha value (KR-20), item-person reliability and separation indices (Table 4). The separation index of persons was used to classify the level of learners. A good separation index should be >2, where the higher the separation index, the better the level of classification of persons. Item separation index was also used to validate the item hierarchy. The low item separation index value, <3 shows that the sample of learners was not large enough to confirm the hierarchy of item difficulty in the instrument. Linacre (2002) insisted that a high separation value indicates that the instrument has good quality since it can identify the group of items and respondents.

Table 4
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)

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Research Results

Content Validity

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 experts' review is necessary to ensure the accuracy of the construct as well as the clarity of its contents. Mullen (2003) remarked that a group of experts are those who are trained in a specific field. Therefore, the researchers showed the ESTT to five experts who had vast knowledge in the fields of entrepreneurial science thinking, Science Education and STEM Education. The researchers used an item evaluation form adapted from the Malaysian Examinations Board (2013). The panel of experts evaluated ESTT items from the aspects of conformity, accuracy, and clarity as well as suitability. Comments from the experts were recorded and taken into consideration for the ESTT instrument improvement process. Table 5 shows the list of experts involved in the content validation panel.

Table 5
Content Validation Panel for ESTT

Name	Institute	Designation	Expertise
Expert A	University	Professor (PhD)	Science Entrepreneurial Thinking
Expert B	Teachers Training Institute (TTI)	Academic Lecturer STEM Department (PhD)	Curriculum and Instructional (Science)
Expert C	Teachers Training Institute (TTI)	Academic Lecturer STEM Department	Science Education
Expert D	Primary School	Head of Science Panel (PhD)	STEM Education and Scientific Creativity
Expert E	Primary School	Science Subject Coach	Science Education (Primary School)

Based on Table 6, all items in ESTT were accepted and the value obtained from the Scale Content Validity Index (S-CVI) was .92. This S-CVI value meets the requirement of ≥ .80 as set by Polit et al. (2017) for new instruments. The S-CVI index of .92 indicated that the expert panel regarded the content validity of the ESTT instrument as very high and acceptable.

Table 6
Content Validity Index (CVI) Results of the ESTT Instrument

Item	Expert A	Expert B	Expert C	Expert D	Expert E	Experts in Agreement	I-CVI	Results
1a	-	/	/	/	/	4	.80	Accepted
1b	-	/	/	/	/	4	.80	Accepted
2a	-	/	/	/	/	4	.80	Accepted
2b	-	/	/	/	/	4	.80	Accepted
3a	/	/	/	/	/	5	1.00	Accepted
3b	/	/	/	/	/	5	1.00	Accepted
4a	/	/	/	/	/	5	1.00	Accepted
4b	/	/	/	/	/	5	1.00	Accepted
5a	/	/	/	/	/	5	1.00	Accepted
5b	/	/	/	/	/	5	1.00	Accepted
Scale Content Validation Index/ Average (S-CVI/Ave)							.92	

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Construct Validity

Person Fit

Table 7 displays the persons (which are the fifth graders in this case), whose responses were most ill-fitting with the Rasch analysis; or in other words, their responses contrasted from the estimation given by the Rasch model. The fifth graders were ranked according to the highest ZSTD Outfit value. Among the fifth graders, there were seven respondents (063, 100, 127, 166, 004, 002 and 022) who scored an Outfit ZSTD value higher than 2.0. The remaining fifth graders scored an Outfit ZSTD value within the acceptable range (from -2.0 to +2.0). Fifth graders whose responses gave negative PTMEA-CORR readings showed that they made decisions out of the usual.

Table 7
Misfit Order of the Persons in ESTT Instrument

Person	MNSQ Outfit (.50-1.50)	ZSTD Outfit (-2.0-2.0)	PTMEA-CORR (.40 - .85)
063	9.90	3.9	- .38
100	9.90	4.5	- .44
127	9.90	3.1	- .25
166	7.33	2.5	- .12
004	5.72	2.8	- .02
002	2.97	2.2	.08
022	2.97	2.2	.08

In addition, there were 10 fifth graders who attained extreme marks (maximum marks) namely, students 020, 044, 068, 076, 084, 088, 093, 096, 109, and 161 (Figure 2). A total of 17 fifth graders were excluded and 149 respondents out of the 166 respondents were involved with the next analysis. This denotes that in the pilot study, the items were fit for almost all the students (89.76%) and the analysis conducted on those fifth graders showed quality findings for the assessment using the Rasch analysis.

Figure 2
Person with Extreme Scores

INPUT: 166 Person 10 Item REPORTED: 166 Person 10 Item 3 CATS WINSTEPS 3.73

Person: REAL SEP.: 2.44 REL.: .86 ... Item: REAL SEP.: 6.86 REL.: .98

Person STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Person
20	30	10	7.51	1.89	MAXIMUM MEASURE				.00	.00	100.0	100.0	020
44	30	10	7.51	1.89	MAXIMUM MEASURE				.00	.00	100.0	100.0	044
68	30	10	7.51	1.89	MAXIMUM MEASURE				.00	.00	100.0	100.0	068
76	30	10	7.51	1.89	MAXIMUM MEASURE				.00	.00	100.0	100.0	076
84	30	10	7.51	1.89	MAXIMUM MEASURE				.00	.00	100.0	100.0	084
88	30	10	7.51	1.89	MAXIMUM MEASURE				.00	.00	100.0	100.0	088
93	30	10	7.51	1.89	MAXIMUM MEASURE				.00	.00	100.0	100.0	093
96	30	10	7.51	1.89	MAXIMUM MEASURE				.00	.00	100.0	100.0	096
109	30	10	7.51	1.89	MAXIMUM MEASURE				.00	.00	100.0	100.0	119
161	30	10	7.51	1.89	MAXIMUM MEASURE				.00	.00	100.0	100.0	161
1	29	10	6.13	1.12	1.18	.5	.79	.3	.22	.29	90.0	90.0	001
3	29	10	6.13	1.12	1.15	.4	.72	.3	.24	.29	90.0	90.0	003
12	29	10	6.13	1.12	1.18	.5	.79	.3	.22	.29	90.0	90.0	012
16	29	10	6.13	1.12	1.08	.4	.59	.1	.28	.29	90.0	90.0	016
19	29	10	6.13	1.12	1.18	.5	.79	.3	.22	.29	90.0	90.0	019

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Item Fit

Linacre (2007) emphasised that the value of MNSQ Outfit provides a strong value in determining the suitability of items for the measurement of a construct. Boone et al. (2014) ascertained that the suitable product value range is between .5 to 1.5 based on MNSQ Outfit, between -2 to +2 range for ZSTD Outfit and between .4 to .85 range for PTMEA-CORR. Any items that are outside the range of Outfit MNSQ, Outfit ZSTD, and PTMEA-CORR are considered inappropriate (Boone et al., 2014). However, if the item meets one of the criteria, the item must be retained (Sumintono & Widhiarso, 2015).

Based on Table 8, there are four items (1, 4, 7 and 9) that are outside the range of items. Boone et al. (2014) and Aziz et al. (2014) stated that items situated outside the range and which do not meet all three criteria are considered unsuitable. However, if the item meets one of the criteria, the item must be retained (Sumintono & Widhiarso, 2015). Table 8 shows that all the items meet at least one criterion. Thus, no items were changed and removed from the instrument.

Table 8
Misfit Order of the Items in ESTT

Item	Outfit MNSQ (.50-1.50)	Outfit ZSTD (-2.0 - 2.0)	PTMEA-CORR (.40 - .85)	Result
I7	1.57	3.2	.54	retained
I2	1.35	.7	.78	retained
I5	1.33	.9	.79	retained
I3	1.26	1.2	.77	retained
I8	.55	- .4	.76	retained
I9	.36	- .9	.69	retained
I6	.92	- .5	.64	retained
I10	.87	-1.0	.85	retained
I4	.67	-2.7	.84	retained
I1	.52	-3.5	.90	retained

Item Polarity

Based on Table 8, the minimum value of PTMEA-CORR is .54 while the maximum value is .90. These positive values indicated that all the items functioned in a parallel direction while negative values showed which items needed to be repaired or dropped. The item polarity analysis using PTMEA-CORR values elucidates that the items in ESTT move in the same direction according to the measured construct (Linacre, 2002).

Unidimensionality

Unidimensionality is important to determine that the instrument being developed can measure in one direction and ensure precise results from the study. Unidimensionality is frequently detected by using the Principal Component Analysis of Rasch Residual (PCAR). Based on Figure 3, the observed value of the Raw Variance Explained by Measures is 66.8%. Values exceeding the 60% index are at an excellent level and it is proven that ESTT instruments have a strong unidimensionality. This shows that ESTT can measure constructs in science entrepreneurial thinking. The value of 6.6% was detected from the Unexplained Variance in the 1st Contrast, which was less than 15%.

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Figure 3

Principal Component Analysis of Rasch Residual (PCAR)

```
INPUT: 149 Person  10 Item  REPORTED: 149 Person  10 Item  3 CATS  WINSTEPS 3.73
--------------------------------------------------------------------------------

     Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)
                                                -- Empirical --    Modeled
Total raw variance in observations     =       30.1 100.0%         100.0%
  Raw variance explained by measures   =       20.1  66.8%          65.7%
    Raw variance explained by persons  =       13.7  45.6%          44.9%
    Raw Variance explained by items    =        6.4  21.2%          20.8%
  Raw unexplained variance (total)     =       10.0  33.2% 100.0%   34.3%
    Unexplned variance in 1st contrast =        2.0   6.6%  19.7%
    Unexplned variance in 2nd contrast =        1.5   5.0%  15.0%
    Unexplned variance in 3rd contrast =        1.2   4.0%  12.1%
    Unexplned variance in 4th contrast =        1.2   3.8%  11.6%
    Unexplned variance in 5th contrast =        1.1   3.7%  11.0%
```

Reliability and Separation Indices

In relevance to the reliability of ESTT, the person measure reliability indicates how well the fifth graders can be distinguished based on their responses. The item measure reliability specifies how well the items (statements) can be discriminated from one another based on their authenticity approved by the respondents. The reliability findings overview is summarized in Table 9.

Table 9 presents the ESTT's reliability values based on Cronbach's coefficient alpha (KR-20). The value achieved was .91. This infers that the reliability of the ESTT is within a very high range (Sumintono & Widhiarso, 2015). The item reliability value of .98 is within a very high range (Bond & Fox, 2007; Linacre, 2007). The item separation index was 7.97, which is more than 3.0. This value proved that ESTT has a good spread of items (Linacre, 2007) that it could distinguish the respondents according to the hierarchy of item difficulty in ESTT.

The person reliability of .89 was also within a good range, whereas the person separation value in ESTT was 2.83. Bond and Fox (2007) stated that the respondents' reliability value, which is higher than .80, indicates that the respondents gave good and consistent feedback. The item separation value of more than 2.00 indicates there is enough spread of items (Linacre, 2002). The value of 2.83 points out that the fifth graders could be divided into three groups according to their responses to the items in ESTT.

Table 9

Summary of the Reliability Findings

	Rasch Measurement	ESTT	Interpretation
Cronbach's alpha (KR-20)	.9 – 1.0	.91	Very high
Item Reliability	>.94	.98	Excellent
Item Separation Index	> 3.0	7.97	Good
Person Reliability	.81 – .90	.89	Good
Person Separation Index	> 2.0	2.83	Good

Discussion

In this research, ESTT was developed to assess the level of entrepreneurial science thinking among fifth graders. In addition to its importance in determining the extent of entrepreneurial science thinking, this ESTT also offers added value in the analysis of entrepreneurial science thinking in STEM Education.

Overall, the Rasch Measurement Model was used to assess the validity and reliability of ESTT. Five constructs,

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namely Observation, New Ideas, Innovation, Creativity and Value, were established as the focus of the ESTT instrument. All ten open-ended items went through the content validation phase by five experts. The items for the Observation Construct were adjusted from observation about energy and the transformation of energy to the observation of building materials and design. This is to guarantee that the scientific principles of materials are tested during the Observation Construct. In addition, the researcher also changed the question's keyword from 'what' to 'explain' for the construction of the New Ideas construct. It is to ensure that fifth graders are subjected to the engagement of high-level thinking.

The construct validity analysis was conducted for item and person fit, item polarity as well as unidimensionality. The results of Rasch's analysis show that ESTT 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 Measures value of the ESTT instrument proved that the ESTT instrument truly measures the construct of entrepreneurial science thinking. In other words, there was no sixth construct in ESTT (Aziz et al., 2015; Fisher, 2007).

The ESTT 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 ESTT instrument was found to have very high Cronbach's alpha value, excellent item reliability value and good person reliability. These findings show that the reliability of ESTT instrument is high in assessing the entrepreneurial science thinking of fifth graders in STEM education. The obtained good item separation value shows that ESTT instrument can be categorized into eight strata of items levels while the obtained person separation value proves that fifth graders can be divided into three strata according to ability level.

Most instruments developed by previous researchers (Li et al., 2016; Bolton & Lane, 2012; Schelfhout et al., 2016) concentrate on high school and undergraduate students' level of entrepreneurial thinking in the field of engineering and entrepreneurship education. This limitation was addressed with the development of ESTT.

Research findings confirm that ESTT is explicitly in line with Kolb (1984)'s experiential learning theory and offer a new instrument for primary school children in STEM education. ESTT helps educators obtain preliminary data on the extent of children's entrepreneurial science thinking in primary schools. The data can then be used to develop appropriate education programs to enhance entrepreneurial science thinking. As reported by Gray (2016), the level of entrepreneurial thinking is essential to anticipate learners' future potential in STEM.

This study has also shown that the level of entrepreneurial thinking among primary school children can be assessed by referring to the appropriate entrepreneurial Thinking Model. Moreover, ESTT utilises an open-ended questions approach, which allows children to offer their views more freely based on their current experience and knowledge (Liñán & Chen, 2009). In addition to that, most previous entrepreneurial thinking instruments used the exploratory factor analysis method, while ESTT uses Rasch analysis, which leads to the accuracy of the instrument developed.

Conclusions and Implications

This research has several implications that impact practicality and methodology. In terms of practicality, the ESTT is a new instrument developed by researchers based on Kolb's Experiential Learning Theory and the Entrepreneurial Science Thinking Model and was adapted to suit the context of STEM Education. Thus, the Entrepreneurial Science Thinking Test (ESTT) instrument is fit to fill the gap in STEM education research and overcome the issue of the lack of instruments that measure entrepreneurial science thinking among primary school children. The development of this instrument is a significant endeavour in warranting the continuity of the application of entrepreneurial science thinking in STEM Education which will ultimately contribute to a generation of inventors and creators.

In terms of methodology, the Rasch Model of Measurement is more specific and detailed in determining the validity and reliability of the ESTT instrument. The Rasch measurement model's analysis of instrument validity in terms of item-person fit, item polarity and unidimensionality showed that ESTT instrument has a high validity in measuring entrepreneurial science thinking in STEM education. The high reliability analysis of ESTT instrument with good item-person separation value proved that ESTT instrument is reliable for measuring entrepreneurial science thinking in STEM education for fifth graders. This study also demonstrated that instruments that have gone through a phase of validity and reliability will help the researcher measure the variables studied and make accurate decisions based on the analysis of the findings. In fact, these findings provide a basis for other researchers so that the ESTT instrument can be distributed to learners in other areas. Ultimately, the validity and reliability

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analysis using the Rasch Measurement Model successfully proved that the ESTT instrument is very suitable for real field study in assessing entrepreneurial science thinking in STEM education among children in primary schools.

Even though the findings suggest that ESTT is a reliable and valid instrument for STEM education, its limitations should be acknowledged. ESTT was tested in five primary urban schools using a sample of 166 fifth graders, it may not be representative of the general population of primary school students. Future research needs to involve a bigger sample size, including rural schools. ESTT can be infused into any STEM curriculum integrated model to promote better critical and inventive thinking skills in STEM. It is suggested to extend the usage of ESTT instrument to other regions of the country, as well as to a variety of learners for greater generalisability.

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Declaration of Interest

Authors declare no competing interest.

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