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THE EFFECTS OF SOCIOSCIENTIFIC ISSUES APPROACH WITH THINKING WHEEL MAPS ON ENTREPRENEURIAL SCIENCE THINKING AMONG FIFTH GRADERS

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Abstract. *This research was conducted to examine the effects of the socioscientific issue approach (SSI) with thinking wheel map (TM) on entrepreneurial science thinking (EST) and the constructs of Observation, New Ideas, Innovation, Creativity, and Value. A teaching and learning (TL) module was developed to guide teachers in implementing the infusion of SSI with TM TL approach on EST among fifth graders. Quasi-experimental quantitative research was conducted on 345 fifth graders in urban primary schools in Malaysia. A total of three TL groups were assigned randomly; namely, i) SSI-TM approach (n=115), ii) SSI (n=115) and iii) Conventional approach (CONV, n=115). The results of the MANCOVA analysis showed a significant effect across the three groups of TL approach for EST. Meanwhile, the ANCOVA analysis results showed a significant effect of the SSI-TM TL approach compared to SSI and CONV on EST and in all constructs of EST. The SSI-TM TL approach showed a higher post-test mean score than the SSI, and then the SSI post-test mean score was significantly higher than the CONV in all constructs studied except the Observation. The findings prove that the SSI-TM TL approach positively impacts the cultivation of EST among fifth graders.*

Keywords: *entrepreneurial science thinking, fifth graders, socioscientific issues approach, thinking wheel map,*

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Introduction

Entrepreneurial thinking has been identified as one of the key cognitive skills that needs to be mastered by students in facing an increasingly challenging future. According to Edwards-Schachter et al. (2015), entrepreneurial thinking is necessary to produce students who can master the characteristics and ethics of entrepreneurship, manage current resources and face future challenges efficiently. These skills enable students to be more critical, creative and innovative thinkers, effective in communicating, and ethical workers (Lekashvili, 2013).

Recalling history, previously the element of entrepreneurship had been applied in the Malaysian school curriculum, for example through the subjects of Basics Finance and Entrepreneurship which were offered to students of the Literature stream only. Although this effort has been made, students have been found to lack the elements and skills of entrepreneurship in their lives (Malaysian Ministry of Education, 2013). Now, global needs and current demands have changed. There is a high demand for the application of entrepreneurial thinking in the school curriculum. Like any other countries, Malaysia is currently preparing school students with the global needs of the world through the Education Blueprint 2013-2025. In the 2017 Revised Primary School Standard Curriculum (Curriculum Development Centre, 2017), elements of entrepreneurship across the curriculum are applied in all subjects including Science. Despite the increased emphasis on fostering students' entrepreneurial thinking in the revised curriculum, there is little evidence to demonstrate research done on entrepreneurial thinking among primary school students. This scenario carries a connotation that a learning approach that integrates innovation and entrepreneurship in the science curriculum needs to be introduced so that the students who are produced are able to create, innovate and have entrepreneurial values thus being able to meet the expected human capital criteria by the year 2030.

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In acquiring entrepreneurial science thinking, a medium that better meets the needs of today's society is very much needed. The socioscientific issue approach (SSI) introduced by Zeidler and Nichols (2009) is very appropriate because of its compatibility with the psychological, social and emotional growth of students and its applicability in various aspects of Science Education. According to Sadler and Zeidler (2009), the socioscientific issues approach is a consistent process in guiding students to apply scientific knowledge and be creative thinkers to create a more competitive future. In fact, through the discussion of social issues with a scientific component related to real life, students can create meaningful learning outcomes in addition to allowing them to connect and apply Science knowledge in an environment outside the classroom (Prain & Tytler, 2012). However, a teaching and learning (TL) approach can only achieve the maximum objective if the teaching medium supports it.

When talking about teaching medium, an added value is needed to make teaching and learning approaches easier to understand and teaching and learning objectives easier to achieve. In this regard, thinking maps (TM) are seen as a tool that can improve thinking skills among students (Hyerle, 2009). In fact, its use has also been identified to increase students' understanding in identifying the potential effects and consequences of science (Saad & BouJaoude, 2012). This is supported by Hmelo-Silver (2004) and Hyerle (2011), who found that problem-based learning with the help of thinking maps can improve students' critical thinking. Therefore, this research was conducted to examine the effects of the socioscientific issue approach with thinking maps (SSI-TM) on entrepreneurship science thinking.

Literature Review

Entrepreneurial Science Thinking

Entrepreneurial thinking (ET) is a cognitive phenomenon that seeks creative and innovative ideas and opportunities (Krueger, 2005). ET is also defined as the ability to identify opportunities in the market and explore appropriate ways to use them (Bacigalupo et al., 2016). In this regard, ET is not a mindset taught to become an entrepreneur alone. However, ET is a skill that can empower human resources, marketability of work and competition. Following this concept of ET, a new concept called entrepreneurial science thinking (EST) was founded by Halim and Buang (Syukri et al., 2013). In this research, EST is referred to as design thinking skills based on scientific knowledge and entrepreneurial orientation (Buang et al., 2009). EST has five constructs which are: (1) Observation: making observations with a plan and purpose; (2) New Ideas: generating ideas by looking for uniqueness or advantages; (3) Innovation: selecting some ideas that can be modified or improved and evaluating those ideas; (4) Creativity: strengthen and improve ideas in a focused manner; and (5) Value: Ensuring that the ideas or products produced are beneficial to society. All steps in this EST are used as the TL phase in the SSI-TM learning module developed by researchers (Ahmad & Siew, 2021a).

EST studied in this research has a clear correlation with the level of cognitive thinking founded by Bloom (1956), namely Knowledge, Understanding, Application, Analysis, Synthesis and Evaluation. Students are asked to make planned and purposeful observations in the Observation construct. The observations require knowledge and understanding to ensure that the observations can be carried out properly. In the New Idea phase, students apply their knowledge and understanding to produce ideas by finding the uniqueness and advantages of a product. Next, in the Innovation phase, students need to do an analysis by choosing some ideas that can be modified or improved and analysing those ideas by justifying the selection factors. Then, in the Creativity phase, students synthesise by combining the selected ideas into a new product design. Finally, in the Value phase, students have to evaluate the new product they create by assessing the advantages of their product to society from the aspect of cost-cutting, product functionality, and ethical value in product creation.

Socioscientific Issues Approach

In cultivating entrepreneurial science thinking, the researcher has chosen the socioscientific issue approach (SSI). SSI is an approach that requires students to make decisions about social issues that involve moral implications in a scientific context (Sadler, 2004; Zeidler & Keefer, 2003; Zeidler et al., 2005). These issues also allow students to study and connect science, daily life, and society in the community (Driver et al., 2000; Sadler, 2004). In SSI-based learning, students are asked to argue and debate in a more conflictual discussion context to discuss current societal issues (Martini et al., 2021). This is in line with the objective of fostering entrepreneurial science thinking, where

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students who can connect science with society are able to produce invented products adapted to the needs of society and solve socioscientific issues that occur in society.

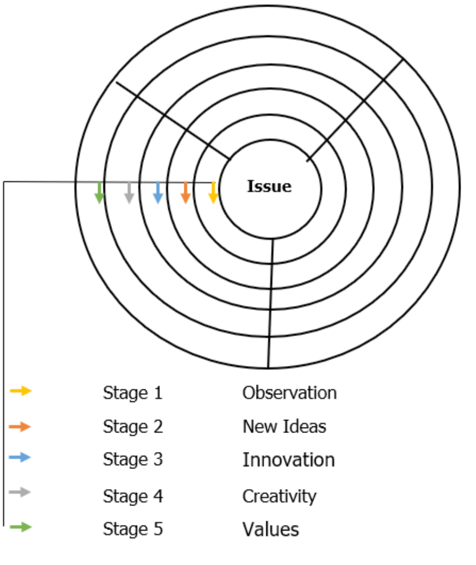
Thinking Wheel Map

Thinking maps are often used as a thinking tool that can improve students' cognitive abilities, such as understanding, analysing, solving problems, and presenting information in visual form (Oxman, 2004). Furthermore, thinking maps help students understand concepts, analyse problems, and find solutions (Hyerle & Yeager, 2007). In this research the researcher used the thinking wheel map (TM) adapted from Bloom (1956), Glenn (1972) and Bengston (2016) (Figure 1). This TM is a thinking tool that helps students identify the implications of a change.

In this research, TM was used in groups through a structured brainstorming process to determine changes and impacts at various levels (Bengston, 2016). The TM contains a centre and five levels to help students generate and organize their ideas. During the use of SSI-TM TL module, students are given socioscientific issues to discuss and argue. At this time, any logical and scientific reasoning ideas are written in the centre of the map. These ideas are the trigger ideas for students to solve in the next stage. Then, students write their ideas at each level according to the constructs of Observation, New Ideas, Innovation, Creativity, and Values. In the first stage, Observation, students are given stimulus pictures that display current product designs. Then, students are asked to make observations to obtain information about the building materials, design, and product characteristics. The second stage is New Ideas, where students produce ideas by finding uniqueness or advantages in the product observed in the building materials, design, and product characteristics. This stage is followed by the third stage, which is the Innovation stage, where students have to choose three out of six uniqueness or advantages in the observed product. Following the selection, students are asked to evaluate the ideas by stating why they choose them.

In the fourth stage, Creativity, students are asked to strengthen and improve ideas in a focused manner based on the ideas selected in the previous step. All of these reinforced ideas are written in the fourth stage of TM. Then, students are asked to sketch and label their product designs on a piece of A3 paper. Students are also required to name their product design and state the selling price and the target group of buyers. All this information needs to be written on the thinking map. Finally, there is the fifth level, Value, where students have to express the values of products that benefit society. Students can express the benefits of cost savings, product functionality, and values and ethics in product creation. The students then present the designed products in front of the class. After that, they explain the benefits of their products with the help of TM.

Figure 1
Thinking Wheel Map



Source: Adapted from Bloom (1956), Glenn (1972) & Bengston (2016)

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Aim

Overall, this research was conducted to determine the effects of the Socioscientific Issue Approach with Thinking Wheel Map (SSI-TM) in fostering the entrepreneurial science thinking of fifth graders compared to the Socioscientific Issue (SSI) and Conventional (CONV) approaches. This research focused on comparisons between two different forms of SSI TL approach, as well as comparisons with non-SSI TL approach in order to determine if other mode of SSI was equally effective in producing desired student outcomes. Consequently, this research was undertaken to further investigate if there were any significant differences in student's entrepreneurial science thinking between learners who were taught in three different TL approaches. The research question that drives this research was: Would students taught via the SSI-TM TL approach perform significantly better than students taught via the SSI approach, who in term perform significantly better than students taught via conventional approach in entrepreneurial science thinking and the constructs of i) Observation, ii) New Ideas, iii) Innovation, iv) Creativity, and v) Value?

Research Methodology

Design

The research employed a quasi-experimental pre-test and post-test control group design to examine the effects of three different TL approaches on fifth graders' entrepreneurial science thinking. The independent variable was the three TL approaches: the SSI-TM (Experimental group), and SSI (placebo group), and the CONV (control group). Dependent variables are based on students' attainment of entrepreneurial science thinking and the constructs of i) Observation, ii) New Ideas, iii) Innovation, iv) Creativity, and v) Value. The research lasted three months from January to March 2021.

Sample

The research population consisted of all fifth graders totalling 4222 people (Tawau District Education Office, 2019) in Tawau district, Sabah, Malaysia. A purposive sampling technique was employed. The schools were selected based on criteria such as the number of classes in the school, socioeconomic background, cultural diversity, and the level of academic performance of students in a school.

A total of 345 fifth graders from four schools were involved as research samples, comprising of 186 (54 %) females and 159 (46 %) males aged 11 years old. In each school, three groups of students were involved and randomly assigned to the SSI-TM approach, the SSI approach and the conventional (CONV) approach. In total, each group of SSI-TM, SSI, and CONV has 115 students.

Teaching and Learning (TL) Approaches

SSI-TM

The SSI-TM learning module was utilized in the SSI-TM TL approach. The SSI-TM module was found to have a valid and reliable content which is feasible in nurturing fifth-graders' entrepreneurial science thinking (Ahmad & Siew, 2022). The SSI-TM learning module was administered in six separate activities in six weeks, with each learning activity would take about 90 minutes to complete. The SSI-TM activities were conducted in groups of four to five students under the facilitation of their teachers. At the end of the learning sessions, the groups presented their sketches and prototypes to the class, while other groups gave comments. From the input given by their peers and teacher, the groups made improvements to their sketches and prototypes.

SSI

The students taught in the SSI group undertook similar learning activities as their counterparts in the SSI-TM group in groups of 4-5 people but were not exposed to the utilization of thinking wheel maps. Students could use i-Think Maps such as Flow Maps to which they had been exposed in previous science lessons to carry out the learning activities.

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CONV

In the CONV TL approach, students completed the learning activities in a conventional way without using SSI-TM module and TM. Students in their own groups built sketches and prototypes. Students approached their teachers for assistance if they encountered problems during the learning activities. At the end of the learning sessions, students made presentations and improvements of their sketches and prototypes as their counterparts in the SSI-TM group and SSI group.

Entrepreneurial Science Thinking Test (ESTT)

In this research, the Entrepreneurial Science Thinking Test (ESTT) was developed to measure students' entrepreneurial science thinking (Ahmad & Siew, 2021b). ESTT has evidence of good construct validity and reliability assessed using the Rasch Measurement Model (MPS) based on the findings of a pilot study involving 166 students. The ESTT test is an instrument of open-ended questions requiring students to answer questions in statements and idea sketches. The constructs in ESTT are built based on the construct of Entrepreneurial Science Thinking (EST) by Buang et al. (2009), namely Observation, New Ideas, Innovation, Creativity, and Value. In ESTT, the main question asked students to produce a future mobile phone design for community use. The context of mobile phone was chosen because it is contained in the Fifth Grade Curriculum and Assessment Standard Document under the theme of Physical Sciences (Curriculum Development Division, 2014). Items are arranged according to constructs to enable students to organize their answers and further lead to the expected findings in the research. Overall, the ESTT includes five constructs and ten items. The ESTT scoring criteria was adapted from Ho et al. (2013), where each item provided in this test carries a minimum score of 0 and a maximum score of 3. Each score is determined based on the level of student answers: Level 1 - 0 marks; Level 2 – 1 mark; Level 3 – 2 marks; and Level 4 – 3 marks.

The validity of the ESTT instrument was evaluated based on item fit analysis using Rasch Measurement Model. According to Boone et al. (2014) and Bond and Fox (2015), three criteria can be used to assess item fit: 1) Outfit Mean Square Values (MNSQ) – the value must be between 0.50 and 1.50; 2) Outfit Z-Standardized Values (ZSTD) – the value must be between -2.00 and 2.00; 3) Point Measure Correlation (PTMEA-CORR) – the value must be between 0.40 and 0.85. If the item meets one of the three criteria, the item should be retained (Sumintono & Widhiarso, 2015). Findings from the assessment of item fit in Rasch analysis show that all items in the ESTT instrument meet at least one criterion for Outfit MNSQ, Outfit ZSTD and PT-MEASURE CORR. This shows that the items in the ESTT instrument are suitable for use in the research sample. In addition, the reliability of the ESTT instrument, which was also analysed using Rasch analysis, reported good index values for item reliability (0.98) and respondent reliability (0.89). In order to assess Inter-Rater reliability, two Science teachers were appointed as examiners to give scores on the answer sheets of 30 students. In this regard, the Pearson value of the correlation coefficient between the two sets of scores was calculated. The analysis results showed that the correlation between the scores for each construct of EST was between 0.873 and 0.901, suggested that the scoring procedure was sufficiently objective.

Data Analysis

The data obtained from the ESTT instrument were analysed descriptively and inferentially using SPSS software version 26. For descriptive analysis, the means (*M*), standard deviations (*SD*) and mean difference (*MD*) were calculated. The mean value for each construct and the whole is using the scale recommended by De Vaus (2002), where the mean classification is according to low, medium, and high levels that can be made by dividing the full value of each construct into three parts according to the context of the research. Table 1 shows the level of analysis and interpretation of the mean in this research.

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Table 1
Level of Mean Analysis and Interpretation of Mean

Level	EST Construct	EST
Low	.00 – 2.00	.00 – 10.00
Moderate	2.01 – 4.00	10.01 – 20.00
High	4.01 – 6.00	20.01 – 30.00

For inferential analysis, multivariate analysis of variance (MANOVA) was used to compare the average score of the answers obtained from the pre-test. Multivariate analysis of covariance (MANCOVA) was used to evaluate the effect of three different teaching and learning groups on the whole and construct of entrepreneurial science thinking. Independent variables identified in previous research as valid predictor variables of dependent variable outcomes can be used as covariates (Field, 2018). Therefore, in this research, the researcher handled six covariates: pre-EST, pre-Observation, pre-New Idea, pre-Innovation, pre-Creativity, and pre-Value. This covariate served as a control variable for teaching and learning groups, adjusting for possible differences between groups. If the overall MANCOVA results were statistically significant, then a series of Univariate Analysis of Covariance (ANCOVA) was performed to determine the significant effect of teaching and learning groups on each dependent variable. The next step of statistical analysis is if the ANCOVA results are statistically significantly different in the three teaching and learning groups, a post-hoc comparison technique is performed to determine which group is significantly different compared to the other group for each dependent variable. The significance level was set at $p < .05$, which means that the researcher determined a difference between the research groups. The preliminary analysis was carried out by the researcher where the prerequisite assumptions of the MANOVA/MANCOVA, namely the identification of outliers, normal distribution, equality of covariance, linearity of variables, multicollinearity, and homogeneity of variance, must be met before testing multivariate statistical findings (Tabachnick & Fidell, 2019). All prerequisite assumptions of MANOVA/MANCOVA have been fulfilled except the assumption of the equality of covariance, where the assumption of the equality of covariance in this research has been violated in the ESTT pre-test [Box's $M = 342.406$, $F(30, 368874.996) = 11.175$, $p < .01$], the ESTT post-test [Box's $M = 287.432$, $F(30, 368874.996) = 9.381$, $p < .01$]. Grice and Iwasaki (2007) emphasized that violations equality of covariance are common and easily overcome using Pillai's Trace. In addition, the effect size (d) is also used in this research to measure the strength of the effect and provide important information in statistical analysis with reference to the value suggested by Cohen (1998).

Research Results

Table 2 compares pre-test and post-test levels for entrepreneurial science thinking (EST) along with its five constructs: Observation, New Ideas, Innovation, Creativity, and Values. Based on Table 2, there is an increase in the mean score level, which is from a medium level to a high level for EST and all the constructs of Observation, New Ideas, Innovation, Creativity, and Value in the SSI-TM group. Meanwhile, for the SSI group, the increase in the mean score level from medium to high level was only found on EST, and the Observation and Value construct. The mean score level for the CONV group remained at a moderate level.

Table 2
Comparison of Mean Score Levels for Entrepreneurial Science Thinking and Constructs in the Pre-test and Post-test.

Construct	TL Approach	*N*	Pre-test			Post-test		
			M	*SD*	Level	*M*	*SD*	Level
EST	SSI-TM	115	12.31	2.206	Moderate	25.90	2.499	High
	SSI	115	12.60	2.320	Moderate	20.51	3.152	High
	CONV	115	12.36	2.606	Moderate	14.97	3.150	Moderate
Observation	SSI-TM	115	2.59	.712	Moderate	5.14	.782	High

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Construct	TL Approach	N	Pre-test			Post-test		
			M	*SD*	Level	*M*	*SD*	Level
	SSI	115	2.65	.761	Moderate	4.84	.894	High
	CONV	115	2.60	.814	Moderate	3.66	1.184	Moderate
New Ideas	SSI-TM	115	2.31	.820	Moderate	5.10	.749	High
	SSI	115	2.46	.666	Moderate	3.92	.860	Moderate
	CONV	115	2.43	.702	Moderate	2.79	.800	Moderate
Innovation	SSI-TM	115	2.28	.720	Moderate	5.17	.737	High
	SSI	115	2.32	.874	Moderate	3.78	.876	Moderate
	CONV	115	2.35	.828	Moderate	2.80	.850	Moderate
Creativity	SSI-TM	115	2.57	.750	Moderate	5.34	.661	High
	SSI	115	2.49	.842	Moderate	3.90	.908	Moderate
	CONV	115	2.47	.680	Moderate	2.77	.726	Moderate
Value	SSI-TM	115	2.56	.728	Moderate	5.17	.700	High
	SSI	115	2.68	.790	Moderate	4.06	.851	High
	CONV	115	2.51	.852	Moderate	2.95	.887	Moderate

Through MANCOVA analysis, the results of Pillai's Trace multivariate test (Table 3) show that overall there is a significant effect of independent variables (teaching and learning (TL) approaches) [F(10, 666) = 42.043, $p < .05$] on entrepreneurial science thinking. However, there was no effect of control variables or covariates (pre-EST) on the dependent variable of entrepreneurial science thinking [F (5, 332) = 1.612, $p > .05$]. The same findings are also seen in the construct of entrepreneurial science thinking, where there is a significant effect of TL approaches [F(10, 666) = 42.043, $p < .05$] on the construct post-Observation post-New Idea, post-Innovation, post-Creativity, and post-Value. However, there was no effect of control variables or covariates (pre-Observation, pre-New Idea, pre-Innovation, pre-Creativity, and pre-Value) on the dependent variable of the post-Observation construct [F (5, 332) = 1.651, $p > .05$], post-New Ideas [F(5, 332) = 1.876, $p > .05$], post-Innovation F(5, 332) = 1.471, $p > .05$], post-Creativity [F(5, 332) = 1.590, $p > .05$], and post-Value F(5, 332) = 1.488, $p > .05$] respectively. This shows that by controlling covariate variables, TL approaches contribute to the mastery of entrepreneurial science thinking and the mastery of the constructs of Observation, New Ideas, Innovation, Creativity, and Values.

Table 3
Summary of the Results of Multivariate MANCOVA and Univariate ANCOVA Tests for the Effect of TL approach and Entrepreneurial Science Thinking Covariate

Effect	MANCOVA			ANCOVA			
	Pillai's Trace *F*	*df*	*p*	*F*	*df*	*p*	Partial ETA Square (η^2)
TL Approach	42.043	10, 666	$p < .05$	393.918	2, 341	$p < .05$	.698
Pre-EST	1.612	5, 332	.156	3.429	1, 341	.065	.010
TL Approach	42.043	10, 666	$p < .05$	74.875	2,341	$p < .05$	.305
Pre- Observation	1.651	5, 332	.146	.091	1, 341	.763	.000
TL Approach	42.043	10, 666	$p < .05$	238.940	2, 341	$p < .05$	.584
Pre- New Ideas	1.876	5, 332	.098	3.490	1, 341	.063	.010
TL Approach	42.043	10, 666	$p < .05$	239.017	2,341	$p < .05$	.584
Pre- Innovation	1.471	5, 332	.199	.235	1, 341	.628	.001

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Effect	MANCOVA			ANCOVA			
	Pillai's Trace *F*	*df*	*p*	*F*	*df*	*p*	Partial ETA Square (η^2)
TL Approach	42.043	10, 666	$p < .05$	309.394	2, 341	$p < .05$	.645
Pre- Creativity	1.590	5, 332	.162	2.578	1, 341	.109	.008
TL Approach	42.043	10, 666	$p < .05$	211.114	2,341	$p < .05$	.553
Pre-Value	1.488	5, 332	.193	.005	1, 341	.942	.000

Further, the researcher conducted an ANCOVA test to identify whether the independent variable (TL approaches) affects the dependent variable, which is entrepreneurial science thinking, and constructs of observation, new ideas, innovation, creativity, and values. ANCOVA analysis shows that there is a significant effect of TL approaches on entrepreneurial science thinking [$F(2, 341) = 393.918$, $p < .05$, $\eta2 = .698$], Observation [$F(2, 341) = 74.875$, $p < .05$, $\eta2 = .305$], New ideas [$F(2, 341) = 238.940$ $p < .05$, $\eta2 = .584$], Innovation [$F(2, 341) = 239.017$, $p < .05$, $\eta2 =. 584$], Creativity [$F(2, 341) = 309.394$, $p < .05$, $\eta2 = .645$], and Value [$F(2, 341) = 211.114$, $p < .05$, $\eta2 = .553$]. The high relationship was found between TL approaches, with the dependent variable showing that 69.8% (entrepreneurship science thinking), 30.5% (Observation), 58.4% (New ideas), 58.4% (Innovation), 64.5% (Creativity), and 55.3% (Value). The variance obtained is taken into account by the SSI-TM TL approach.

Post-Hoc analysis was also performed to determine the effect of the independent variable on the dependent variable. Table 4 shows the results of pairwise comparison tests and effect sizes for the effect of TL approaches on EST, along with the constructs of Observation, New Ideas, Innovation, Creativity, and Values. Pairwise comparison shows that the SSI-TM TL approach is significantly higher than the SSI approach for the entire EST as well as all the constructs in the EST ($p < .05$) except for the Observation construct ($p = .062$). Meanwhile, the pairwise comparison also shows that the SSI-TM approach is significantly higher than the CONV approach for the entire EST and all constructs ($p < .05$). The same finding is also seen in the pairwise comparison between the SSI and CONV approaches, where the SSI approach is significantly higher than the CONV approach for the entire EST as well as all constructs in the EST ($p < .05$).

For the effect size analysis, in the aspect of EST as a whole, students exposed to the SSI-TM TL approach showed a larger effect size ($d = 1.89$) than the SSI approach. In addition, a large effect size was also seen in the comparison between the CONV approach with the SSI-TM ($d = 3.84$) and SSI ($d = 1.76$) approaches. The same findings can also be seen on all constructs in EST except for the Observation construct. In this regard, the SSI-TM approach showed a small effect size compared to the SSI approach in the Observation construct ($d = 0.36$). Statistically, the SSI-TM approach effectively improves entrepreneurial science thinking and constructs New Ideas, Innovation, Creativity, and Value.

Table 4
Pairwise Comparison Test Results and Effect Size for the Effect of TL approaches on Entrepreneurial Science Thinking along with Constructs

Construct	Pairwise comparison	*MD*	*p*	*d*	Interpretation (Cohen, 1988)
EST	SSI-TM vs SSI	5.417	$p < .05$	1.89	Big
	SSI-TM vs CONV	10.894	$p < .05$	3.84	Big
	SSI vs CONV	5.477	$p < .05$	1.76	Big
Observation	SSI-TM vs SSI	0.298	.062	0.36	Small
	SSI-TM vs CONV	1.480	$p < .05$	1.48	Big
	SSI vs CONV	1.182	$p < .05$	1.12	Big
New Ideas	SSI-TM vs SSI	1.173	$p < .05$	1.46	Big
	SSI-TM vs CONV	2.312	$p < .05$	2.98	Big

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	SSI vs CONV	1.139	$p < .05$	1.36	Big
Innovation	SSI-TM vs SSI	1.384	$p < .05$	1.71	Big
	SSI-TM vs CONV	2.365	$p < .05$	2.98	Big
	SSI vs CONV	0.982	$p < .05$	1.14	Big
Creativity	SSI-TM vs SSI	1.428	$p < .05$	1.81	Big
	SSI-TM vs CONV	2.543	$p < .05$	3.70	Big
	SSI vs CONV	1.115	$p < .05$	1.37	Big
Value	SSI-TM vs SSI	1.105	$p < .05$	1.42	Big
	SSI-TM vs CONV	2.217	$p < .05$	2.78	Big
	SSI vs CONV	1.112	$p < .05$	1.28	Big

Discussion

The mastery of entrepreneurial science thinking has shown that the mean score for the SSI-TM TL approach is significantly higher than the SSI and CONV approaches. This finding shows that the intervention of SSI-TM that applies the socioscientific issue approach and the thinking wheel map provides a systematic and structured space for students to develop their entrepreneurial science thinking. Furthermore, exposure to the SSI-TM module allows students to produce unique products by finding uniqueness or advantages in existing products. The socioscientific issue approach encourages students to observe existing products and identify the advantages and uniqueness of those products so that more creative products can be produced (Goodman & Lim, 2018; Ward & Broniarczyk, 2016). In the investigation of uniqueness and advantage, the use of a thinking wheel map helps students make research uniqueness in a more structured way, reveal their abstract concepts and share ideas among group members more systematically (Omar et al., 2020). Due to the ability of the socioscientific issue approach to improving entrepreneurial science thinking, the implementation of the socioscientific issue approach with the help of a thinking wheel map is highly encouraged in the teaching and learning of Science (Friedrichsen et al., 2016).

Even so, for the Observation construct, the difference in mean scores for students who follow the SSI-TM and SSI approaches is insignificant. This proves that TM does not help students improve the observation construct. In improving the observation construct of entrepreneurial science thinking, the approach to socioscientific issues alone is sufficient. This is due to the ability of the socioscientific issue approach to increase student involvement in learning and arguing about issues of community benefit (Owens et al., 2017), which leads to a significant increase in knowledge (Sadler, 2011). Students in the SSI group exposed to socioscientific issues provide a meaningful learning experience to increase students' level of observation and understanding regarding an issue (Zeidler, 2016). Focused socioscientific issues revealed to students how to increase students' powers of observation where they need to observe many things, including the characteristics of objects, building materials, and the design of existing objects (Topçu et al., 2018). The significant increase for the SSI group also shows that the approach of socioscientific issues that highlight social issues around students stimulates low-level thinking, such as making preliminary observations. This is in line with Piaget's Theory of Cognitive Constructivism, which states that based on early observations, with the help of an environment with various signs, symbols, and tools, a more progressive process will occur and create a higher level of the thinking process. In this context, the cultivation of constructs after Observation is more high-level, namely New Ideas, Innovation, Creativity, and Values in the thinking of entrepreneurial science.

In the context of improving the New Idea construct of entrepreneurial science thinking, the SSI-TM approach in this research displays a significant improvement with a large effect size compared to the SSI and CONV approaches. Coinciding with the use of SSI, students were exposed to various socioscientific issues that could lead to differences of opinion among students based on their respective beliefs. Scientific and social knowledge built as a result of a debate among students that is shared among them will generate their ideas to identify the uniqueness or advantages found in the objects they observe (Walker & Zeidler, 2007). In the SSI-TM TL approach, students are given space to argue critically, provide justification and reasoning for each argument they argue (Martini et al., 2021) and record all their ideas in the second stage of the thinking wheel map systematically. The infusion of the socioscientific issue approach, together with the thinking wheel maps, allows students to easily record any of their ideas in a systematic approach (Bengston, 2016). Any idea thought to be logical and compatible with the

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observed uniqueness or advantage is included in the second stage of the TM. This makes it easier for students because the concept of levels in the wheel helps in the rapid collection of data to find the uniqueness or advantage of an observed object. As a result, the infusion of SSI with TM can help students master the construction of New Ideas where the TM is easy for students to understand and stimulate their systematic thinking during the group brainstorming process (Krueger, 2005).

Next, the dominance of the Innovation construct has also shown that the mean score for the SSI-TM TL approach is significantly higher than the SSI and CONV approaches. At the same time, the SSI approach also showed a significantly higher mean score than the CONV approach. The infusion of the socioscientific issue approach and the thinking wheel map helps students select ideas more easily because all the new ideas that have been identified have been expressed in the previous second stage. With the help of the SSI-TM approach, the selection can be made more efficiently compared to the SSI approach, which requires students to make the selection abstractly in their minds. At this stage of Innovation, students should analyse by making the best choice of ideas from the uniqueness and advantages of the products listed before and justify the evaluation made. This is where the thinking wheel map helps in mastering the Innovation construct. The increase in the mean score for students who follow SSI-TM compared to SSI and CONV can also be explained by the ability of SSI to infuse with TM in fostering the construct of Innovation. In mastering the Innovation construct, students need to do research before choosing a unique product idea to be developed (Crespi & Scellato, 2015). In this regard, mapping in the wheel map helps students make the best choices to ensure that the unique ideas chosen at this stage can lead to the production of creative and innovative products (Najafi-Tavani et al., 2018).

The intervention carried out for the SSI-TM TL approach with the help of TM also positively impacted the mastery of the Creativity construct. This clearly shows that the activities designed based on the infusion of SSI and TM have the potential to help students to strengthen and improve ideas in a focused way based on the ideas selected in the previous step. In this construction, students express ideas that have been improved by making design sketches, labelling, and building product design models. Students are then asked to state the product's name, the price offered, and the target group of buyers for the product. Careful planning of activities in this teaching and learning module can help students to explore various possibilities and stimulate students to produce something new, more unique, and cutting-edge (Repenning et al., 2021). The use of SSI together with TM also helps increase students' scientific knowledge when they explore the given socioscientific issues (Topçu et al., 2018). Apart from that, teaching through SSI also allows students to explore the ideas and practices of science involved in social phenomena and can help improve students' critical thinking skills to produce new ideas (Lindahl et al., 2019).

For the Value construct, a significant mean score difference for the SSI-TM group shows that the use of this approach is proven not only to improve students' scientific knowledge but also to encourage students to argue about the effects and consequences of a scientific issue on society's morality (Zeidler, 2016). In this regard, SSI-TM gives students the opportunity to consider the issues that occur, evaluate statements, analyse evidence, and evaluate various views on ethical issues through discussion and debate. This can clearly help in fostering the fifth construct of EST, which is Value, where students need to ensure that the ideas or products produced are beneficial to the community. In addition, through the Value construct, students are also trained to relate ethical issues in product creation. This can be realized through SSI-TM TL approach because students will be actively involved in the issue debate process, especially in matters involving ethical issues (Lindahl et al., 2019). In addition, the learning concept for the SSI-TM TL approach organizes students' ideas through the consideration of socioscientific issues from various aspects of life (science concepts, student needs, society, economy, politics, and the environment), which also affects the mastery of this construct.

Conclusion and Implications

The results of the research showed a significant positive effect of the SSI-TM TL approach compared to SSI and CONV approaches in improving entrepreneurial science thinking and its constructs: New Ideas, Innovation, Creativity, and Value. Nevertheless, for the Observation construct, it was found that the SSI TL approach recorded an insignificant improvement compared to the SSI-TM and CONV approaches. Overall, the cognitive effects obtained show that the implementation of SSI-TM TL approach is better than SSI and Conventional approaches. This proves that the infusion of SSI and TM TL approaches in the teaching and learning process can make teaching based on explicit thinking to be implemented. This situation can improve the mastery of the lesson's content and the aspect of students' entrepreneurial science learning.

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This research shows that the use of learning modules that lead to the enhancement of students' entrepreneurial thinking can be implemented starting at the primary school level. The use of thinking wheel maps is very helpful in organizing and organizing data in a systematic and planned manner. Therefore, students can apply the use of thinking wheel maps not only in TL, but also in the implementation of co-curricular activities such as science clubs and so on.

In fact, the collaborative discussion activities in the SSI-TM TL approach imply the need for peer collaboration to create an active and conducive learning environment. Students need to act more proactively in finding information in arguing and finding solutions to a socioscientific issue. In addition, the presentation session can be implemented continuously in other TL sessions due to its ability to improve students' ability to analyse and evaluate the strength of a product in addition to increasing students' confidence to explain their opinions.

In fact, this research implies that it is necessary for teachers to provide learning activities about thinking and for thinking more explicitly to students. In the implementation of thinking learning, teachers first need to equip themselves with argumentation skills, decision-making skills and knowledge in the socioscientific issues that are discussed. In relation to that, this research implies that teachers need to constantly explore socioscientific knowledge in order to easily become an expert to be referred by students during TL sessions. Apart from socio-scientific knowledge, teachers also need to master the method of applying the thinking wheel map in teaching to make it easier for teachers to carry out TL activities that can improve students' entrepreneurial science thinking.

This research focuses on the effects of SSI-TM on entrepreneurial science thinking through the infusion of socioscientific issue approaches and thinking wheel maps for fifth graders. Therefore, for future research, the researcher proposes to conduct an SSI-TM infusion approach for fourth grade and upper-secondary students, which will provide variation from gender differences and school location differences. The target focus sample can also be widely distributed to students in rural schools. Therefore, the researcher suggested that future researchers can fill the gaps by involving other themes with socioscientific issues to be highlighted.

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Declaration of Interest

The authors declare no competing interest

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