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EFFECTS OF SOCIO-SCIENTIFIC ISSUES BASED ON THINKING MAPS APPROACH ON FUTURE THINKING OF SECONDARY SCHOOL STUDENTS

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Abstract. *This study was conducted to examine the effects of the socio-scientific issue (SSI) approach assisted by the future thinking map (FTM) on five constructs of future thinking, namely i) understanding the current situation, ii) identifying the trends, iii) analyzing the relevant drivers, iv) synthesizing the possibilities or needs of the future and v) choosing with the justification of the desired future. The future-thinking test instrument was developed to measure the level of future thinking. A quasi-experimental pre-test and post-test control group design was employed. A total of 255 form four students (age 16) from three randomly selected rural secondary schools in Tawau District, Malaysia were assigned to i) SSI-FTM (n = 85), ii) SSI (n = 85), and iii) conventional (CV, n = 85) teaching and learning (TL) strategies. The results of the MANCOVA analysis showed that there was a statistically significant effect across all three groups of TL strategies. The ANCOVA analysis showed that there was a statistically significant effect of the SSI-FTM TL strategies compared to the SSI and CV TL strategies on the five future thinking constructs. The quasi-experimental study proves that the SSI-FTM TL strategy is effective in nurturing future thinking among form four students in science lessons.*

Keywords: *future thinking, future thinking map, secondary schools, socio-scientific issue*

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Introduction

Knowledge gained through attaining future thinking in a field helps students connect the present with the future (21st Century Fluency Series, 2016). Describing future entities through a relationship built from various aspects of life creates a community of people who actively investigate all possibilities, predict future needs, and create the desired future (Hines & Bishop, 2012). Furthermore, Jones et al. (2012), who conducted a study on New Zealand curriculum reform at every level of education, found that future thinking can be honed as early as pre-school education up to the university level. However, the movement of researchers at the international level is not in line with the focus of researchers in Malaysia, who are more focused on researching the attainment of high-level thinking skills. Thus, this research unravels two questions: (1) Can future thinking be nurtured among students?, and (2) what are the effective teaching and learning (TL) strategies in cultivating future thinking among students?.

Research Problem

The information boom of the 21st century and the development of the Industrial Revolution 4.0 has led the international community to focus on the implementation of a socio-scientific issue (SSI) approach to improve future thinking (Bolstad, 2011; Buntting & Jones, 2015; Jones et al., 2012; Paige et al., 2018). Generally, this approach is based on issues or phenomena in students' real lives. It assimilates with scientific elements that require students to go through a process of reasoning about values and ethics and triggering possible ideas to solutions based on issues or topics raised (Kristóf, 2006; Pinzino, 2012; Zeidler & Nichols, 2009). A socio-scientific learning framework that focuses on three main dimensions, namely i) teacher, ii) social, and iii) learning environment, is capable of training students to become future thinkers and, at the same time, inculcate a high scientific literacy (Jimenez-Aleixandre & Osborne, 2012).

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However, Berkowitz (1997), Kristóf (2006), Sadler (2004), and Zeidler and Keefer (2003) argued that the lack of wise judgment in the selection of socio-scientific issues (SSI) by educators also contributes to the weakness of attainment of future thinking among students. The use of contemporary issues that do not stimulate students to think ahead resulted in students being unable to predict, infer, make hypotheses, and extrapolate in identifying possibilities, needs, and selection of decisions needed in the future. According to Albe (2008), the selection of appropriate socio-scientific issues prepares students to relate scientific knowledge to current situations and the ability to predict things that are likely to happen in the future.

According to Driver et al. (2000), Evagorou et al. (2012), and Zeidler et al. (2009), the discussion and debate on the SSI approach provide a framework for understanding science content while enhancing students' future thinking. Nevertheless, the discussion and debate for this approach require educators to be competent in its implementation, making this approach less popular to be implemented in the classroom. Facione and Facione (2007), Jones et al. (2012), Row et al. (2016), and Zeidler and Nichols (2009) argued that the implementation of the SSI approach requires teachers to act as facilitators and play an important role in ensuring students use optimal cognitive capacity through the process of linking, analyzing, synthesizing, predicting, making choices to plan, and creating the desired future. Lack of competence and understanding of how the SSI approach work results in students' future thinking not being fully stimulated (Leadbeater, 2011).

The success and failure of teaching and learning are also influenced by selecting and applying appropriate teaching aids or materials. Therefore, the selection of appropriate teaching aids is an aspect that needs to be given due emphasis. This is also explained by Jones et al. (2012) and Zeidler (2016), who argued that the presentation of structured data and complex relationships would engage students in the production of actions, selections with justifications and solutions that students think are appropriate. Although the thinking map is a new element in the field of education in Malaysia, the reference for its application and implementation is similar to the types of i-think maps that have been absorbed into the education system through the Malaysia Education Blueprint 2010-2025 (Ministry of Education Malaysia, 2013). Nevertheless, the opposite phenomenon occurs when Daliyanie (2011) states that students nowadays seem to be shaped through curriculum machines and learning in schools is only focused on using textbooks as teaching aids.

To some extent, the lack of systematic and specific guidelines in the implementation of SSI has a negative impact on the stimulation of students' future thinking. The lack of guidelines has made it difficult for teachers to guide students to visualize something outside the context of the classroom and to predict the next 20 to 30 years compared to what students are facing now. This is also agreed by Leadbeater (2011) and Row et al. (2016), in the implementation of the SSI approach, teachers should have a systematic guideline to facilitate them to link students' existing knowledge with knowledge that students do not yet know. Therefore, due to these constraints, there is a need for further research to be carried out to develop the future thinking module as well as to evaluate its impact on the future thinking of students.

Research Aim and Research Hypotheses

The positive effects of integration of SSI with the future thinking maps (FTM) approach are less reported on specific aspects of future thinking of form four students who take science subjects. Therefore, the overall aim of this study was to assess the effects of SSI-FTM on nurturing the five constructs of future thinking among form four students, such as understanding the current situations, identifying trends, analyzing relevant drivers, synthesizing future possibilities or needs and choosing with justification the desired future. Accordingly, this study was focused on testing the hypothesis of the 'integration approach' versus the 'non-integration approach'. The study aimed to investigate the extent to which SSI-FTM and SSI nurture students' future thinking. In addition, this study also explores the TL strategies of SSI-FTM and SSI compared to conventional (CV) TL strategy. As such, three TL strategies were used in this study: SSI-FTM, SSI and CV. Thus, the hypotheses of this study are as follows:

Students who are taught using the SSI-FTM TL strategy are significantly performed better than students who are taught using the SSI TL strategy, next students who are taught using the SSI TL strategy are significantly performed better than students who are taught using the CV TL strategy for the constructs of understanding the current situation, identifying the trends, analyzing relevant drivers, synthesizing possibilities or future needs, and selecting with justification the desired future.

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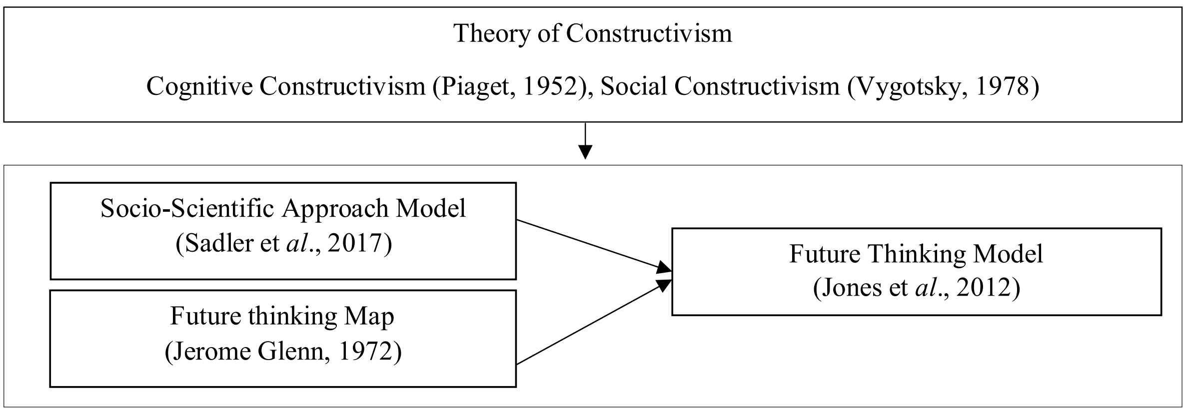
Literature Review

Theoretical Framework of SSI-FTM TL strategy

The SSI-FTM TL strategy is developed based on two main learning theories, namely Piaget's Theory of Cognitive Constructivism (Piaget, 1952) and Vygotsky's Social Constructivism (Vygotsky, 1978).), and two models of i) Socio-scientific Learning (Sadler et al., 2017), ii) Future Thinking (Jones et al., 2012) and iii) Future Thinking Map (Glenn, 1972). The combination of these theories, models, and teaching aids in the context of this study is a solid foundation and guide to ensure SSI-FTM TL strategy is developed according to the level and development of children, as well as a guide and scaffolding in this study. Overall, the theoretical framework used in this study is summarized in Figure 1.

Figure 1
Theoretical Framework of the Study



Lee dan Abd-Ei-Khalick (2006) argued that there are four important features of constructivism theory that have implications for SSI, namely i) the mind develops, changes and adapts to issues that occur when interacting with existing schemata and the environment, ii) understanding is gained through the interaction of socio-scientific issues, iii) information seeking to create solutions to socio-scientific issues stimulates students' cognitive development, iv) knowledge is built through social collaboration and assessment of the diversity of views. The characteristics and functions of FTM as a thinking tool are appropriate in translating students' thinking systematically and by future-thinking patterns (Bengston, 2015; Glenn, 1972; Jones et al., 2012).

The socio-scientific approach model (Sadler et al., 2017) is one of the main conceptual models in developing the SSI-FTM TL module. The model consists of two sections, namely i) the sequence of learning that must be present in the implementation of SSI, and ii) the various learning objectives that can be achieved through the implementation of SSI (Figure 2). The first section consists of three main phases, namely i) issues of focus, ii) student involvement in scientific knowledge, science practice and socio-scientific reasoning practice, and iii) synthesis and practice of idea. The SSI sequence is divided into three main phases starting with the issues of focus. This is to ensure that students can understand how the ideas and principles of science are related to social issues and the problems that arise from the issues used. According to Abd Rahim (2017), SSI learning should emphasize the involvement of students in the practice of science content to assist in creating a productive and substantive science learning experience related to social issues. The second phase provides a platform for teachers to encourage students to actively find the intersection between social issues, scientific knowledge, and scientific practice to make issues more complex, interesting, and difficult to solve, known as socio-scientific reasoning (Sadler et al., 2017). The final phase in SSI learning demands that the development of the SSI TL module should encourage students to synthesize ideas and practices.

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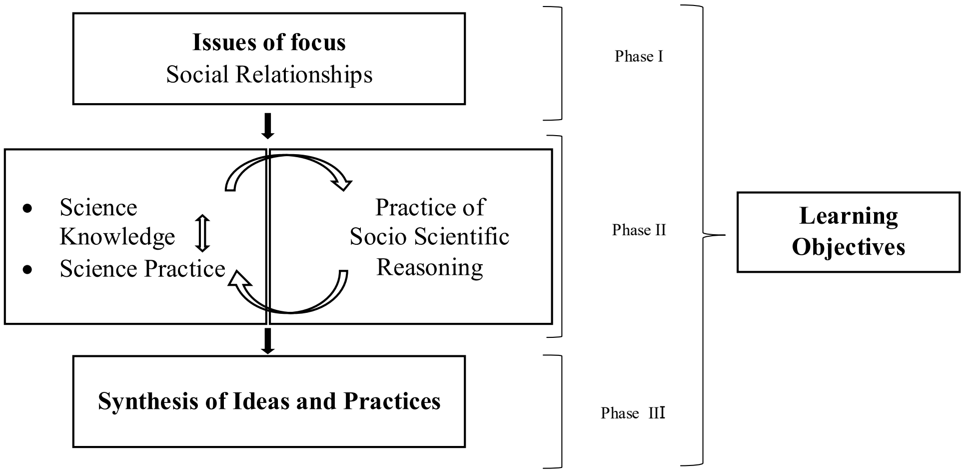
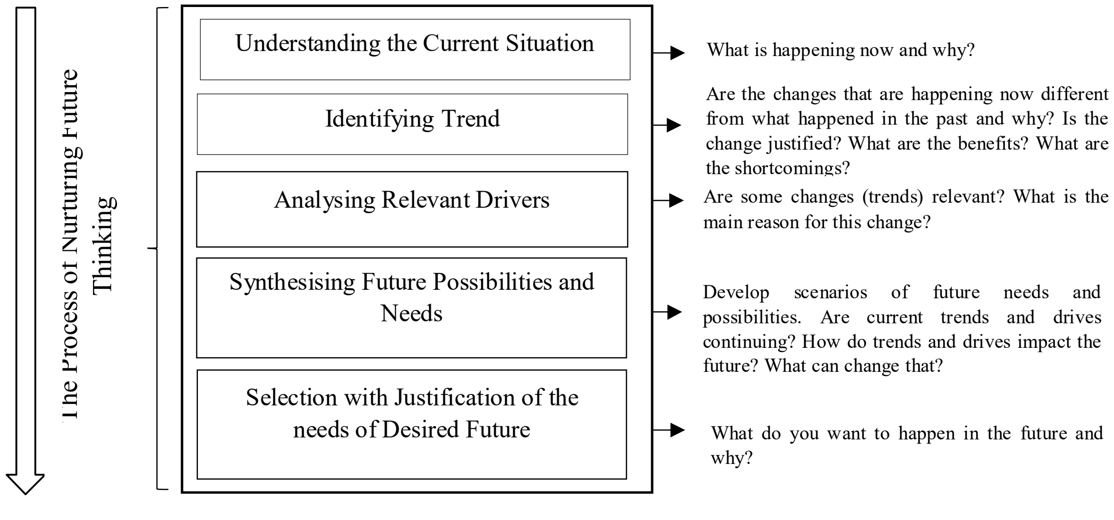
Figure 2
Socio-scientific Approach Model (Sadler et al. 2017)



The details of Figure 3, in turn, display the future thinking model consisting of five thinking constructs founded by Jones et al. (2012), that is, i) understand the current situation, ii) identify the trends, iii) analyze relevant drivers, iv) synthesize future possibilities and needs, and v) selection with the justification the desired future. The construct of understanding the current situation is an attempt to explore events holistically, channel scientific knowledge and connect the context with individual and social aspects (Hodson, 2003). The trend identification construct refers to the pattern change in the event that can be observed in the present or seen in the future and is due to a change in the driving force (Rialland & Wold, 2009). The construct of analyzing relevant drivers is the analysis of the factors that cause the change, influence, or impact something (Saritas & Smith, 2011). The fourth construct in future thinking refers to the effort to make the future more realistic in decision-making to produce new thoughts and decisions, learning how to think by seizing all the opportunities available to be explored (Jones et al., 2012). The final construct in future thinking is the hopes, aspirations and dreams desired for the future through the exploration of the available opportunities (Hicks, 2012).

Figure 3
Future Thinking Model (Jones et al., 2012)



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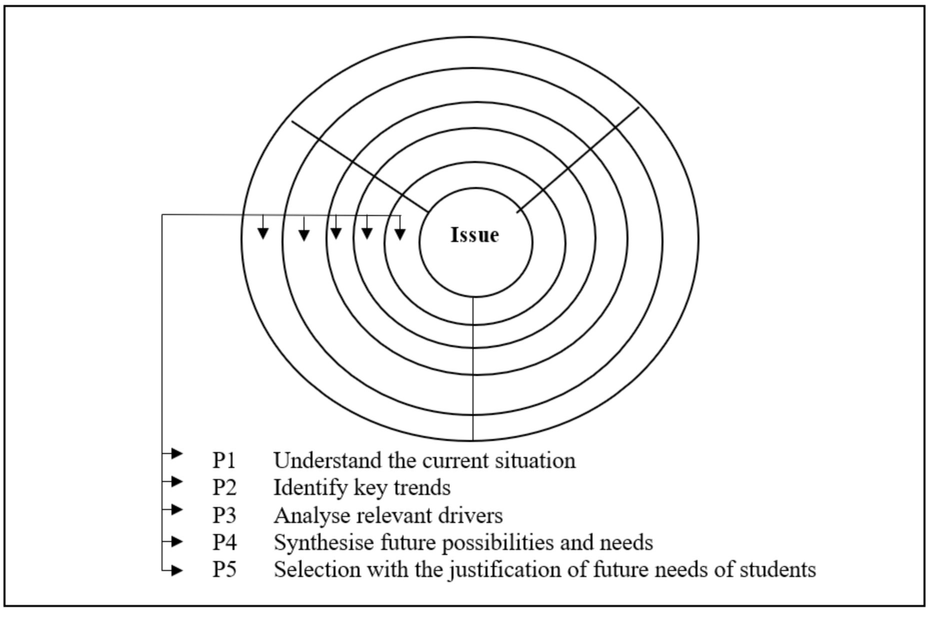
While the future thinking map (FTM) (Figure 4) adapted from Glenn (1972) was used as a visualization and thinking tool to guide students in the discussion of activities in the developed module. The first prerequisite in using FTM is the map's center as the group discussion's initial focus. Details about the center of the FTM should be given to students who do not have in-depth knowledge of a change. Most researchers present an issue as central to FTM and can be shown in the form of audiovisuals, excerpts, or newspaper clippings. While the second prerequisite, according to Surowiecki (2004) and Page (2007), is that members in the group should be composed of various cultures, ethnicities, knowledge, gender and age to enhance a more effective effect in the discussion. According to Schreier (2005), there are five levels in the FTM. The first level is a step to prepare students to list the characteristics based on the issues in the center of FTM and then identify the differences between the past and the present. The second level discusses more specifically the significant changes or trends that can be observed in the current scenario. According to Schreier (2005) and Jones et al. (2012), students at the third level are looking for the drivers that cause change. At the fourth level, students are required to use high-level thinking to predict and synthesize any possibilities and needs in the future based on trends and drivers that have been identified. At this level, students should be able to develop scenarios for synthesizing future possibilities and needs. Finally, the fifth level requires students to analyze the future effects, opportunities and potential and then justify the choices made per future needs.

Figure 4
Future Thinking Map adapted from Glenn (1972)



Conceptual Framework

Based on the theory, model and literature review, the researcher presents a conceptual framework of the study that focuses on SSI-FTM to determine its effects on future thinking for the physical theme of Form Four science. The conceptual framework of the study is an illustration of the effects of independent variable on dependent variable. Overall, the framework of the study is summarized in Figure 5.

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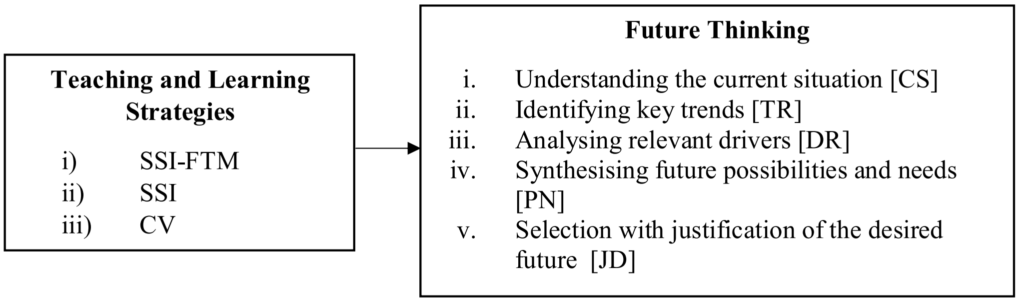
Figure 5
Conceptual Framework of the Study



Research Methodology

Research Design

This study used a quasi-experimental pre-test and post-test control group design to examine the effects of three different teaching and learning (TL) strategies on future thinking. The independent variables were three TL strategies: SSI-FTM, SSI (placebo group) and conventional (control group). Dependent variables are based on students' attainment of future thinking for five future thinking constructs, namely i) understanding the current situation, ii) identifying trends, iii) analyzing relevant drivers, iv) synthesizing future possibilities or needs and v) selection with justification of the desired future.

Sample

The study population consisted of 842 form four students of rural secondary schools in the Tawau district (Tawau District Education Office, 2019). A total of three rural category schools fully funded by the Ministry of Education Malaysia were selected based on the acquisition of equivalent pre-future thinking test scores. The three schools in the same category also aimed to reduce the demographic disturbance factor of the study sample in the study findings. A total of 255 students were involved, with 85 students selected from each school with the consent of the Principal and the Tawau District Education Office. The study sample consisted of 96 males (37.6%) and 159 females (62.4%) aged 16 years. Each selected school was divided into three randomly selected classes to qualify as a whole group: the SSI-FTM, SSI, and CV. All 255 students involved in this study were given the intervention in the same week but with different teaching strategies for nine weeks between Mac - August 2019.

Instrument

This study uses a Future-Thinking Test (FTT) instrument developed by the researcher (Siew & Abdul Rahman, 2019) and was adapted from the study of Jones et al. (2012). FTT consists of 5 items and 6 sub-items for the theme of Physical Science. The validity and reliability analysis of FTT is based on the Rasch Measurement Model, which was conducted on 66 study samples (36 females and 30 males aged 16 years) from two rural secondary schools in Tawau District, Sabah, Malaysia. Overall, FTT has good reliability with a Cronbach's Alpha (KR-20) value of 0.69. The results also show that FTT has excellent item reliability and moderately high values of 0.97 and 5.92. FTT also has sufficient reliability and individual separation values of 0.67 and 1.41. The unidimensionality analysis of FTT found that the value of Raw variance explained by measures 51.7% and Unexplained variance in 1st contrast 10.4% did not exceed the control limit set by the Rasch Measurement Model, and the Eigen value located at Unexplained variance in 1st contrast was 2.6 not more than 5 indicating FTT is unidimensional and there is no second dimension in measuring future thinking.

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Teaching and Learning (TL) Strategies

SSI-FTM

The learning module utilized in the SSI-FTM TL strategy was developed by the researchers (Abdul Rahman & Siew, 2019). The SSI-FTM learning module consisted of six learning activities that studied Physical Science topics in the Form Four Science Curriculum. A socio-scientific issue without rigid answers were first presented to allow students to reflect on the social and scientific practice. For example, 'In your opinion, should the production and use of plastic material be stopped to protect our environment?'. Students then carried out the learning activities using the FTM. The scenario posed in the learning activities entailed the changes which occurred in the students' daily lives. One sample of the learning activities related to the scenario was:

> "*Classrooms have changed a lot over the last hundred years. Changes in classroom are not specific to its layout but the change in infrastructure as well. Are these changes desirable? How will the classroom of the future look like?*

Students were required to first understand the given current scenario, list out its features. and give reasons why the features were such as stated in the scenario. Students list out the differences between the classroom in the past and today based on the scenario given. Students were also instructed to give major changes (trends) that could be observed in the classroom today and give the underlying causes (drivers) for those changes. Next, students were to answer advantages and disadvantages of these drivers respectively. Students were required to give reasons as to whether these trends and factors would continue to affect a classroom in the future. Students were also required to give the possibilities of a future classroom in line with the development of factors and changes in the classroom today. Students were then asked to produce and label the sketches of a future classroom model if they were given the opportunity to build a classroom for community use in the next 70 years. Students then named their future classrooms and stated the materials used while providing justifications for the selected features for their future classrooms.

The SSI-FTM activities were conducted in groups of four to five students under the facilitation of their teachers. Each learning activity would take about 90 minutes to complete. The learning activities were carried out in five levels via future thinking maps (FTM) drawn on a piece of mahjong paper. The construction of FTM involves two steps on a piece of mahjong paper namely a) making the fold, and b) drawing a line on the fold. The empty space between the folds forms a level that allows students to write their ideas on it.

With these FTM, all the group members had an equal opportunity to expand their ideas using the same mahjong paper. In order to establish a meaningful discussion, students were encouraged to share their thoughts and views with one another, and entertained viewpoints from peers and facilitators. With the help of more capable peers, teachers and FTM, students developed their five constructs of future thinking in the given learning tasks.

SSI

The students taught in the SSI group undertook similar learning tasks as their counterparts in the SSI-FTM group in groups of 4-5 people but were not exposed to the utilization of future thinking maps. Students could use graphic organizers such as mind-maps to which they had been exposed in previous science lessons to carry out the learning activities. At the end of the learning sessions, the groups shared their results with the class, while other groups made their comments. From the input given by their peers and teacher, the groups made improvements to their future models.

CV

In the CV TL strategy, students completed the learning tasks in a conventional way without using SSI-FTM learning modules and FTM. Students in their own groups used textbooks as the main reference in finding answers to the learning activities. However, the answers to each activity were still regulated and given by the teacher. As the students encountered problems during the learning activities, they approached their teachers for assistance.

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At the end of the intervention, a post-test was administered on all three groups of TL strategies and mean scores were calculated as an indicator of the change of their future thinking.

Data Analysis

Descriptive statistics were calculated for means (M), standard deviations (SD) and mean difference (MD). The MD measures the absolute difference between the mean value in two different groups. The equivalence of the research groups was examined using MANOVA through the scores obtained from pre-test. In this study, the Pre-CS, Pre-TR, Pre-DR, Pre-PN, Pre-JD served as covariates to adjust for possible pre-existing differences between the TL groups.

Preliminary Analysis

Preliminary analysis was conducted to check whether the prerequisite assumptions of MANOVA/MANCOVA were met. Thus, the assumptions to MANOVA/MANCOVA in the statistical analysis were examined for: (a) multivariate normal distribution, (b) equality of group population covariance matrices, (c) linear relationship between covariates and dependent variables, (d) absent of multicollinearity, and (e) homogeneity of dependent variable variance. The assumptions that were used for the MANCOVA/MANOVA and inferential statistics analyses were tested using SPSS for Windows (Version 24). Alpha value (*p*) was set at 0.05 level of significance.

Pre-Experimental Research

The purpose of pre-experimental research was to test the assumption that the respondents across the three TL groups were equivalent in their future thinking of Pre-CS, Pre-TR, Pre-DR, Pre-PN, Pre-JD. One-way multivariate analysis of variance (MANOVA) was performed to examine if there were statistically significant differences among the students' mean score on Pre-CS, Pre-TR, Pre-DR, Pre-PN, Pre-JD across the three TL groups. If the overall multivariate test (MANOVA) was not significant, univariate F test (ANOVA) was examined to further examine if there were significant statistical differences between the respondents across the three TL groups in each of the pre-test.

A multivariate analysis of covariance (MANCOVA) was conducted (with pre-tests as the covariates) to investigate the main effects of the three different TL strategies on respondents' Post-CS, Post-TR, Post-DR, Post-PN, and Post-JD, while controlling the five covariates. By employing the MANCOVA, the extraneous differences among groups can be controlled after removal of the effects of covariates from the dependent variables (Hair et al., 2010). If the overall multivariate test (MANCOVA) was significant, univariate F test (ANCOVA) was carried out on post-test mean scores with pre-test mean scores as covariates to further examine if there was a significant statistical main effect of TL groups on each of the post-tests.

The effect size index (*f*) and eta square (η^2) were calculated. According to Cohen's characterization, $0.2 \leq f < 0.5$ is deemed as a small effect size, $0.5 \leq f < 0.8$, a medium effect size, and $f \geq 0.8$ as the large effect size. For interpreting η^2, $0.010 \leq \eta^2 \leq 0.039$ = small, $0.039 < \eta^2 \leq 0.11$ = medium, and $0.11 < \eta^2 \leq 0.20$ = large effect size (Cohen, 1988, p. 284-288).

Research Results

Preliminary Analysis

Preliminary analysis indicated adequate conformity to all univariate and multivariate assumptions of MANOVA/MANCOVA for: (a) multivariate normal distribution, (b) equality of group population covariance matrices, (c) linear relationship between covariates and dependent variables, (d) absence of multicollinearity, and (e) homogeneity of dependent variable variance.

Descriptive Statistics

The descriptive statistics of students' pre-test and post-test scores on their five constructs of future thinking are summarized in Table 1.

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Table 1
Descriptive Statistics of the Dependent Variables

Dependent variables	TL Group	N	Pre-test		Post-test	
			M	SD	M	SD
Understanding the current situation [CS]	SSI-FTM	85	1.95	.66	2.91	.27
	SSI	85	1.82	.60	2.84	.24
	CV	85	1.90	.69	1.73	.76
	Total/Average	255	1.89	.65	2.49	.73
Identifying key trends [TR]	SSI-FTM	85	2.15	.78	2.83	.52
	SSI	85	2.19	.74	2.34	.25
	CV	85	2.22	.68	1.11	.60
	Total/Average	255	2.18	.73	2.09	.87
Analyzing relevant drivers [DR]	SSI-FTM	85	2.06	.71	2.78	.29
	SSI	85	2.12	.68	2.40	.49
	CV	85	2.11	.71	0.88	.47
	Total/Average	255	2.10	.70	2.02	.93
Synthesizing future possibilities and needs [PN]	SSI-FTM	85	.73	.49	2.69	.49
	SSI	85	.71	.56	2.18	.61
	CV	85	.70	.508	0.89	.70
	Total/Average	255	.71	.52	1.92	.97
Selection with justification the desired future [JD]	SSI-FTM	85	1.41	.33	2.90	.41
	SSI	85	1.42	.33	1.89	.31
	CV	85	1.46	.36	1.09	.70
	Total/Average	255	1.43	.34	1.96	.89

The Pre-experimental Research Results

The results of MANOVA and ANOVA indicated that there were no significant statistical differences across the three groups in Pre-CS, Pre-TR, Pre-DR, Pre-PN, and Pre-JD (Table 2).

Table 2
Summary of Multivariate Analysis of Variance (MANOVA) Results and Followed-up ANOVA Results on Pre-test Mean Scores

MANOVA effect and dependent variables	Multivariat F	Univariat F
	Pillai's Trace df = 10, 498 F=.384, P=.954	df = 2, 252
Pre-CS		F=.77, P=.46
Pre-TR		F=.19, P=.82
Pre-DR		F=.23, P=.79
Pre-PN		F=.07, P=.92
Pre-JD		F=.49, P=.61

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The Experimental Research Results

The results of MANCOVA analysis with pre-test as covariate showed that there is a significant effect of TL strategy [Pilai Trace = .556, F (2, 247) = 60.32, p < .05] on five constructs of future thinking. Further the results of ANCOVA analysis showed that TL strategies had a major effect on the construct of CS [F (2, 251) = 186.58, p < .05, η^2 = .598], TR [F (2, 251) = 287.36, p < .05, η^2 = .69], DR [F (2, 251) = 469.29, p <.05, η^2 = .79], PN [F (2, 251) = 196.131, p <.05, η^2 = .61] and JD [F (2, 251) = 279.12, p < .05, η^2 = .69].

In addition, Post Hoc analysis (Table 3) showed the existence of a large effect size in comparisons between SSI-FTM and CV TL strategies in CS (2.33), TR (3.05), DR (4.9), PN (2.96), and JD (3.17). While the comparison between SSI-FTM and SSI also displays a large effect size magnitude for constructs of CS (0.87), TR (1.19), DR (0.92), PN (0.93), and JD (2.78). In addition, Table 3 also displays large effect sizes in comparisons between the SSI TL strategy and the CV TL group for the constructs of CS (1.96), TR (2.68), and DR (3.17), PN (1.96), JD (1.49). Overall, the study findings are summarized in Table 3.

Table 3
Summary of Post Hoc Pairwise Comparison

Group Comparison	*MD*	*p*	*f*	Interpretation
Understanding the Current Situation (CS)				
SSI-FTM vs SSI	0.15	.05	0.87	Big
SSI-FTM vs CV	1.25	.05	2.33	Big
SSI vs CV	1.10	.05	1.96	Big
Identifying Trends (TR)				
SSI-FTM vs SSI	0.48	.05	1.19	Big
SSI-FTM vs CV	1.71	.05	3.05	Big
SSI vs CV	1.23	.05	2.68	Big
Analyzing Relevant Drivers (DR)				
SSI-FTM vs SSI	0.37	.05	0.92	Big
SSI-FTM vs CV	1.90	.05	4.90	Big
SSI vs CV	1.52	.05	3.17	Big
Synthesizing Future Possibilities or Needs (PN)				
SSI-FTM vs SSI	0.51	.05	0.93	Big
SSI-FTM vs CV	1.80	.05	2.96	Big
SSI vs CV	1.28	.05	1.96	Big
Choosing with Justification the Desired Future (JD)				
SSI-FTM vs SSI	1.00	.05	2.78	Big
SSI-FTM vs CV	1.81	.05	3.17	Big
SSI vs CV	0.81	.05	1.49	Big

Discussion

Overall, the results of this study indicate that students taught through the SSI-FTM TL strategy are significantly better than students taught through the SSI TL strategy in five constructs of future thinking, namely i) Understanding the current situation, ii) Identifying the trends, iii) Analyzing relevant drivers, iv) Synthesizing future possibilities or needs, and v) Selecting with justification the desired future. Similarly, it was found that students taught through the SSI TL strategy also performed better than those taught through the CV TL strategy in the five constructs of future thinking. The significant effect size in comparing i) SSI-FTM and CV TL strategies and ii) SSI-FTM and SSI TL strategies, respectively, showed that the SSI-FTM TL strategy was the most effective of the three strategies in promoting

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the five future thinking constructs. In addition, students taught through the SSI strategy outperformed students taught through the CV TL strategy with a large effect measure.

The SSI-FTM TL strategy based on socio-scientific issues and assisted by FTM provided a meaningful learning experience for students to understand a situation in their environment. FTM provided an opportunity for students to communicate actively in groups in the generation of ideas which needed to be written in the space provided in the first level of FTM. The FTM stimulated students to list the characteristics and reasons based on the socio-scientific issues in the middle of the FTM. This helped the students to use their cognitive capacity optimally while increasing their understanding of the current situation compared to their peers in the SSI and CV groups. Shabiralyani et al. (2015) and Raiyn (2016) also agreed that using visual materials could stimulate thinking, be a catalyst for discussion, and enhance the quality of learning. Without FTM in the SSI and CV TL strategy reduces the opportunity for students to participate in discussions and provide explanations on socio-scientific issues, thus reducing their ability to understand the current situation. This is also expressed by Yacoubian and Khisfe (2018), who agreed that SSI is an effective method of teaching science at school. However, suppose students are not engaged in teaching and learning aids; in that case, it will cause them not to be involved in exploring profound socio-scientific issues, thus inhibiting their understanding of the current situation.

The findings of this study also showed that ability of identifying trends among SSI-FTM students is better than their peers learned in the SSI and CV TL strategy. Teaching and learning through the SSI-FTM strategy that focuses on activities in listing the differences between past and present phenomena in the second level of FTM can strengthen students' ability to compare the differences and further identify the trends. In addition, the levels of FTM also helped students to collaborate in organizing ideas from discussions and exchanging ideas between group members in a more systematic way. The findings also support the evidence from the study by Siew and Mapeala (2016) which revealed that thinking maps is an effective tool in improving the ability to organize ideas systematically.

The third level of FTM helped students to develop the skills of analyzing drivers through two stages of learning, namely i) group discussion in analyzing drivers based on the trends identified in the second level and ii) critical argumentation in considering the advantages and disadvantages of drivers from the aspects of science concepts, society, economy, technology, and materials. These two stages of learning enhance students' ability to analyze the drivers that cause the change and advantages and disadvantages of these drivers. This finding is supported by Inayatullah (2014), who found that the ability to build relationships between levels helps develop analytical skills among future thinkers.

The fourth level of FTM requires students to explore various possibilities or future needs based on the trends and drivers identified in the second and third levels of FTM. According to Petrakis and Konstantakopoulou (2015), identifying patterns and trends encourages strategic thinking in predicting future possibilities for a desirable and feasible future. Through this process, students could improve their ability to analyze, synthesize, and choose appropriate strategies for their desired future needs. This is also supported by Pisapia et al. (2005) that the skill of synthesizing does not only focus on components and relationships, but it involves an understanding of directions and patterns that will open space for appropriate action.

SSI in this study which focused on scientific arguments from various disciplines, was not enough for students to develop the skills of synthesizing future possibilities or needs compared to the SSI-FTM group. According to Kreibich et al. (2011), approaches that do not apply appropriate thinking tools will cause difficulties in building students' ability to synthesize possibilities or needs in the future. The findings of this study are also in line with the findings of studies conducted by Boujaoude (2000) and Deal (2002). They found that the lack of use of a thinking map will result in students being unable to relate relationships and present complex relationships visually while creating unsystematic exploration.

Through the activity of connecting and extracting ideas from the entire levels of the FTM, students increased their understanding of possible implications and chose the desired future with justification. This is because students can use the ideas displayed on the levels in the FTM to build and plan the future for specific reasons. The entire FTM allows students to comprehensively understand the possible implications. This can be used as a preparation and alternative to face or avoid it by giving more rational justifications. The use of socio-scientific issues such as problems in society, health, environmental pollution and so on strengthened the ability of students to choose the desired future in solving the existing problems.

The SSI TL strategy used in this study involved brainstorming activities and the generation of ideas to improve students' ability to understand the current situation well and then develop other future thinking constructs

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compared to the CV TL strategy. However, the SSI TL strategy that does not use FTM in every learning activity has resulted in students being less able to relate to relationships and present complex relationships visually, creating unsystematic exploration. This impact is also highlighted by Lederman and Lederman (2014) and Yacoubian and Khisfe (2018), who argued that students could not use cognitive capacity optimally for thinking critically and analytically in understanding, identifying, analyzing, and synthesizing socio-scientific issues if students are not exposed to teaching aids.

The CV TL strategy applied a single teaching mode where the teaching process emphasizes the concept of finding answers, but less space was created for students to discuss and think. Students became passive learners and put the teacher at the center of learning. This is supported by Slavin (2019), who stated that conventional learning is ineffective in producing active learning and less stimulating students in discussions in the classroom. Prince (2004) added that the regulation of answers that still depends on the teacher limits the ability of students to develop ideas. This was expressed by Zhou (2018), who stated that CV learning that emphasizes one-way interaction between teachers and students causes students not to participate actively even though students work in small groups. This finding supports the view of Alexander et al. (2011) and Pescatore (2007) in that students' thinking ability in learning cannot occur randomly. It requires structured exposure for students to construct and stimulate thinking in finding existing patterns based on ongoing phenomena. For these reasons, students taught in the CV TL strategy did not perform comparably to those taught using the SSI-FTM and the SSI TL strategies in the five constructs of future thinking.

Conclusions and Implications

Overall, this study has shown the positive effects of the SSI-FTM TL strategy in promoting the five constructs of future thinking, namely i) understanding the current situation, ii) identifying the trends, iii) analyzing relevant drivers, iv) synthesizing future possibilities or needs and v) choosing with justification the desired future. This clearly shows that integrating the SSI-FTM TL strategy that integrates socio-scientific issues and future thinking maps in the science classroom is capable of training students to become future thinkers who are able to identify possibilities, needs, and selection of decisions needed in the future. In addition, the inclusion of socio-scientific elements and socio-scientific issues in the teaching and learning of science can increase students' awareness of the need to consider all aspects of life and the impact they will have on the future.

This study only involves topics for physical science themes in the form four Science syllabus, so it is hoped that the scope of topic selection is expanded to several other topics or subjects, using a mixed method in data collection, and involving a larger number of samples to reconfirm the effects of SSI-FTM TL strategy on future thinking.

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Declaration of Interest

The authors declare no competing interest.

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