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Concept Mapping Plays Important Roles on Students' Critical Thinking Skills in Science

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Abstract: The lack of students' critical thinking skills especially in Science can affect the Malaysia education system. This study aimed to identify the effectiveness of Collaborative Concept Mapping (CCM) and Individual Concept Mapping (ICM) in improving students' critical thinking skills in science subjects. This study used the quasi-experimental research design that involved 189 form one students from public secondary schools in Malaysia. The manipulated variable in this study is teaching approaches, which includes Collaborative Concept Mapping (CCM), Individual Concept Mapping (ICM) and conventional method (CM). Meanwhile, the dependent variable is students' critical thinking skills in Science. Data was collected using critical thinking skills diagnostic tests and analysed using one-way ANOVA test. The one-way ANOVA indicated that the students in CCM group showed significantly higher level of critical thinking skills as compared to those in the ICM and CM groups. While, there is no significant difference in the level of critical thinking skills between students in ICM and CM groups. Therefore, CCM is effective in fostering students' critical thinking skills compare to ICM and CM teaching approaches. CCM can be used as an alternative teaching approach in science classroom to enhance students' critical thinking skills.

Keywords: Concept mapping, Collaborative concept mapping, Critical thinking skills, Science education

Introduction

Thinking skills should not only be applied to students, but it should also be an important agenda in community development in order to produce citizens who can play their role to be critical, creative, competent and responsible to the country (Curriculum Development Division, MoE, 2017; Marin & Halpern, 2011; Sarimah Kamrin & Shaharom Noordin, 2008; Economic Planning Unit, 2001). Education without prioritizing the development of thinking skills is like 'palace without pillar'. A good educational system for a country is to create a society capable of thinking and possessing universal standard intellectuals (Abdul Rahim, 1999; Elder & Paul, 2008; Sarimah Kamrin & Shaharom Noordin, 2008; Scriven & Paul, 2004).

In Malaysia, thinking skills have been introduced in the national education system since the reconstruction of the Secondary School Integrated Curriculum (KBSM) in the year of 1988 known as Critical and Creative Thinking Skills (KBKK). KBKK is still ongoing even though the country's curriculum is changing and undergoing improvement in the Secondary School Standard Curriculum (KSSM) beginning in the year of 2017. Researcher chose Critical Thinking Skills (KBK) as the main focus of the study because critical thinking skills should first be mastered by students before they can master creative thinking skills (Anderson et al., 2001; Anderson & Krathwohl, 2001; Marin & Halpern, 2011; Ghani et al., 2017; Cañas et al., 2017).

Research Background

The ability to think critically is seen by many world-class academic scholars as one of the basic requirements for educated minds (Boyd, 2001; Brookfield, 1989; Elder & Paul, 2008, 2009; Facione & Facione, 1996; Ghani et

al., 2017; Cañas et al., 2017). Therefore, critical thinking skills are important in the teaching and learning process in the classroom so that it is in line with the expectation of the Ministry of Education Malaysia (MOE) to produce more students who understand their minds.

In addition, the importance of critical thinking skills can also be seen through the goal of KBSM science curriculum aimed at enabling students to master scientific skills and thinking skills and apply their knowledge and skills in a critical and creative way based on scientific attitudes and values in problem solving, decision making and conceptualization (Curriculum Development Division, MoE, 2011). The importance of the critical thinking skills were also outlined in the KSSM by expressing the curriculum's aspiration to create critical, creative, innovative and skillful citizens who embark on Science, Technology, Engineering and Mathematics (STEM) to achieve developed nation status (Curriculum Development Division, MoE, 2015).

Problem Statement

Science average score for Malaysia in 2015 Trends in International Mathematics and Science Study (TIMSS 2015) assessment was below the international average score guideline. Malaysia's ranking was lower than the other Asian countries. Although TIMSS 2015 recorded increasing in the Science average score which is 471 points higher than the points received in the previous TIMSS in the year of 2011 which is 426 points, it is still considered as the bottom line performance when the average score is below 500 points (Education Policy Planning and Research Division, MoE, 2016).

The weakness of Malaysian students to obtain a higher average score and a better position for Malaysia in the TIMSS is that the assessment measures the ability of students to solve problems critically rather than memorizing the facts because the cognitive domains tested in TIMSS are knowledge (30%); application (35%); and reasoning (35%). The application domains instruct students to compare, classify, use a model, connecting, interpreting information, finding solutions and to explain, while the reasoning domains instructs students to analyze, synthesize, make a hypothesis, designing, make conclusion, make generalization and last but not least is to evaluate. All these instructions are the key elements associated with critical thinking skills.

In this regard, MoE has outlined the three approaches that should be considered in handling the teaching and learning process of Science which are teaching ways to think, teaching to think and teaching about thinking. By prioritizing activities that can apply critical thinking skills in teaching and learning process, Malaysia's achievement of Science subject in TIMSS can be improved and helps students in mastering the critical thinking skills.

However, teaching of thinking skills is still poorly applied by teachers during the process of teaching and learning in Science (Sadiah Baharom, 2008; Sarimah Kamrin & Shaharom Noordin, 2008; Marin & Halpern, 2011; Leach & Good, 2011; Kamisah Osman, Wahidin & Subahan Mohd Meerah, 2013). Several studies that have proven the lack of the thinking skills in school students (Sarimah Kamrin & Shaharom Noordin, 2008; Akbariah, 2009; Fan Yan, 2015; Simon, 2013). Thus, there is a need to improve the teaching and learning Science in order to increase the level of proficient of critical thinking skills among school students (Sarimah Kamrin & Shaharom Noordin, 2008; Simon, 2013).

Therefore, teaching approach that able to address the acquisition of students' critical thinking skills in Science classroom, should be planned and implemented. The suggestion of the teaching approaches in the Science classroom are the teaching modules named Collaborative Concept Mapping (CCM) and Individual Concept Mapping (ICM).

Research Aim

This research aims to look into the effectiveness of the teaching modules: Collaborative Concept Mapping (CCM) and Individual Concept Mapping (ICM) towards increasing the level of critical thinking skills among the students in Science subject.

The research question of the study is: To what extend Collaborative Concept Map (CCM) and Individual Concept Map (ICM) teaching modules effect student's critical thinking skills in Science? Following the research questions, two null hypotheses are developed in the study:

Ho_1: There is no significant mean difference in the initial Science critical thinking skills score among students who follow the CCM, ICM and CM teaching approaches.
Ho_2: There is no significant mean difference in the final Science critical thinking skills score among students who follow the CCM, ICM and CM teaching approaches.

Literature Review

One of the ways to address the lack of students' critical thinking skills especially in science subject is to focus on teaching strategies based on the constructivism theory. (Lawson, 2001, Sadiah Baharom, 2008; Sarimah Kamrin & Shaharom Noordin, 2008; Effah Moh et al., 2013; Cañas et al., 2017). The concept mapping approach is based on constructivism (Novak & Gowin, 1984; Novak & Cañas, 2004, 2008; Harris, 2008; Bixler et al., 2015; Ghani et al., 2017; Cañas et al., 2017). In addition, concept mapping is suitable to be used in teaching and learning processes in Science with the aim to nurture and improve critical thinking skills among students.

Constructing concept maps requires systematic procedures and thus using critical thinking skills and teaching critical thinking skills to students also requires systematic procedures (Dewey, 1933, Novak & Govin, 1984; Anderson et al., 2001; Anderson & Krathwohl, 2001; Novak & Cañas, 2004; 2008; Cañas et al., 2017). In other words, concept mapping approaches can meet the need to use critical thinking skills and also meet the need to teach critical thinking skills.

Thus, the concept mapping approach is the most appropriate approach to use during the Science teaching and learning process especially with the aim of nurturing and improving students' critical thinking skills in Science. Concept mapping approach can be implemented either collaborative or individual.

Collaborative Concept Mapping (CCM) can help students build the knowledge/conceptual framework actively and train the use of critical thinking skills more frequently by structuring a large number of new information in existing knowledge/conceptual frameworks through discussions between members in a collaborative group (Quitadamo, 2000; Harris, 2008; Barchok, Too, & Ngeno, 2013). According to Gokhale (1995), exchanging ideas among members in the group is a major behavior that helps to develop critical thinking skills as conversations can stimulate students' thinking.

Individual Concept Mapping (ICM) provides an opportunity for students to take their individual time (individual pace) in building a knowledge/conceptual framework and getting autonomous in choosing what knowledge/concepts to understand about the learning topic and more open in understanding their own abilities and weaknesses (Khajavi & Ketabi, 2011).

However, very few studies have proven that concept mapping approaches are appropriate to improve student critical thinking skills (Cañas et al., 2017). Past studies are more focused on using concept mapping methods with the aim to understand the concepts of a particular science topic (Roop, 2002; Harris, 2008; Sadiah Baharoom, 2008; Gray, 2014; Fan Yan, 2015; Richbourg, 2015). Most of the previous studies that investigate the link between concept mappings with critical thinking skills had been done in areas other than Science education field (Vacek, 2009; Nirmala & Shakuntala, 2011; Bekelesky, 2015).

Methodology

This study uses the quasi-experimental design which applied a Reversed-Treatment Control Group (Shadish, Cook, & Campbell, 2002). Table1 shows the research design of the study.

Table 1. Quasi experimental design

Groups	Pre-test	Intervention	Post-test
First treatment	O_1	X_+	O_2
Second treatment	O_1	X_-	O_2
Control	O_1	X_0	O_2

Note
O1 : Pre-test
O2 : Post-test
X_+ : Collaborative Concept Map (CCM)
X_- : Individual Concept Map (ICM)

X_0 : Conventional method (CM)

This design is chosen because it has the advantage of increasing the internal validity of the study since the second treatment group acting as a "reverse effect" (Shadish, Cook, & Campbell, 2002) which may occur due to the absence of collaborative components in concept mapping interventions. "Reverse effects" may occur when part of the intervention component is eliminated which causes intervention not to affect as expected. The first treatment group is designed to study the effect of concept mapping with collaborative components on students' critical thinking skills in Science.

While, the second treatment group acts as a "reverse effect" detector (Shadish, Cook, & Campbell, 2002) and aims to control the effect of 'Hawthorne' that may exist when implementing a new intervention (Cook & Campbell, 1979; Cherry 2008; Burton, 2010). The second group used intervention of concept mapping without the collaborative components.

Sample

The population of the study was a form one students (13 years old) in public secondary schools in Malaysia. The total number of samples for this study was 189 students. Table 2 shows the profile of students involved in this study as well as the interventions provided during the teaching and learning process.

Table 2. Study samples' profile

Total Num.	Groups	Total	Class	Total	Intervention
189	First treatment	63	First treatment 1	32	CCM
			First treatment 2	31	
	Second treatment	62	Second treatment 1	31	ICM
			Second treatment 2	31	
	Control	64	Control 1	30	CM
			Control 2	34	

Students involved in the study were taken from intact classes or existing classrooms in the school as this study was conducted during regular school hours (Campbell & Stanley, 1963) so as to avoid interruptions.

Instrumentation

Data collection method was through quantitative method which is by pre-test and post-test score. Data was collected through Science Critical Thinking Skills (SCTS) diagnostic tests. The SCTS test is a Science test that embodied elements of critical thinking skills. The format of the test is based on the Form Three Assessment (PT3) requirement and are based on the Standard Document of Curriculum and Assessment of Form One (DSKP) (Ministry of Education, 2015) which consist of multi-form objective questions, limited respond questions and open respond questions (Ministry of Education, 2014). The open respond questions are the higher order thinking (HOT) questions which asking the students to analysis data, give ideas based on the correct concepts, valuing and reasoning the choice they choose and detected biased on the stated opinion or concepts.

In addition, these items are taken from form one science textbooks and reference books, and collection of actual exam questions based on the Form Three Assessment (PT3) format developed by Ministry of Education (2014). Researcher also used booklets available on the guide to form higher order thinking (HOT) questions by Ministry of Education (2014) and booklets on High-Level Thinking Skills Assessment by Ministry of Education (2013). The test was administered for CCM, ICM and CM groups before (pre –test) and after (post-test) the respective intervention was completed.

Findings and Discussion

The one-way ANOVA analysis was conducted to determine whether there is significant mean difference in the initial Science critical thinking skills score among the students who follow the CCM, ICM and CM teaching approaches. One-way ANOVA test result is shown in Table 3.

Table 3. One-way ANOVA analysis for initial Science critical thinking skills score of the students in all groups of teaching approaches

	Sum of Square	df	Mean Square	F	Sig. (p)
Between Groups	1.509	2	.754	.209	.812
Within Groups	672.819	186	3.617		
Total	674.328	188			

One-way ANOVA analysis showed that there was no significant mean difference in the initial Science critical thinking skills score among the students who follow the CCM, ICM and CM teaching approaches where, [F (2, 186) = .209, p = .812 and p> 0.05].

In conclusion, the result of this analysis showed that there was no significant difference in the mean score of initial Science critical thinking skills among students in the three groups of teaching approaches before being exposed to any intervention, hence the Ho1 Hypothesis failed to be rejected.

The one-way ANOVA analysis was conducted to determine whether there was a significant mean difference in the final Science critical thinking skills score among the students who follow the CCM, ICM and CM teaching approaches. The test's result is shown in Table 4.

Table 4. One-way ANOVA analysis for final Science critical thinking skills score of the students in all groups of teaching approaches

	Sum of Square	df	Mean Square	F	Sig. (p)
Between Groups	486.086	2	243.043	7.951	.000
Within Groups	5685.353	186	30.566		
Total	6171.439	188			

From one-way ANOVA analysis, there was a significant difference in the final Science critical thinking skills score between the three groups [F (2, 186) = 7.951, p = .000 and p <0.05. Meanwhile, the results of the Post-Hoc Scheffe (Pallant 2011) test for the multiple comparisons of students between groups of teaching approaches summarized in Table 5.

Table 5. Post Hoc Scheffe test analysis of students between groups of teaching approaches
Dependent Variable: final critical thinking skills

(I) teaching approaches	(J) teaching approaches	mean difference (I-J)	Std. Error	Sig. (p)	95% Confidence Interval	
					Lower Bound	Upper Bound
1 CCM	2 ICM	2.966*	.989	.012	.53	5.41
	3 CM	3.705*	.981	.001	1.28	6.13
2 ICM	1 CCM	-2.966*	.989	.001	-5.41	-.53
		.739	.985	.755	-1.69	3.17
	3 CM	-3.705*	.981	.001	-6.13	-1.28
3 CM	1 CCM	-.739	.985	.755	-3.17	1.69
		2.966*	.989	.012	.53	5.41
	2 ICM	3.705*	.981	.001	1.28	6.13

*The mean difference is significant at p = 0.05

Based on Table 5, there was a significant difference in the mean score of the final Science critical thinking skills for the group of students who followed the CCM teaching approach with ICM [ΔM = 2.966, p = .012 and p <0.05] and CCM with ICM [ΔM = 3.705, p = .001 and p <0.05], while the group of students following ICM and CM teaching approaches did not show significant mean difference in mean [ΔM = .739, p = .755 and p> 0.05]. As a result of this analysis, there was a significant difference in the mean score of the final Science critical thinking skills among students in the three groups after being intervened, hence Ho2 hypothesis was rejected.

The findings suggest that, the CCM teaching module/approach is effective in fostering students' Science critical thinking skills compare to ICM and CM teaching approaches. This is because, CCM is a combination of concept mapping learning method and collaborative learning method, making it a teaching approach that combines the advantages of both learning methods (Basque & Lavoie, 2006; Torres & Marriott, 2010).

Moreover, there is a sharing of information/ideas/concepts between students in a CCM group. This was agreed by Gokhale (1995) and also other researchers such as Bixler, et al (2015); Ghani et al. (2017); and Cañas et al. (2017) where they think, the conversation and mutual-exchange ideas between members in a collaborative group were the main behaviours that helped to foster critical thinking skills as it stimulated students to think. If there are four students in a collaborative group, then a student will receive information/ideas/concepts three times more than the students study individually.

In other words, students in the CCM group receive more information/ideas/concepts as the stimuli to think and they need to process the information they received more often compare to the students in ICM and CM groups and likely, they will think more. To assist in processing this 'vast' and 'abundant' information, students are suggested to use the concept map (Novak & Cañas, 2004, 2008; Harris, 2008; Sadiah Baharoom, 2008; Kinchin et al., 2014 Cañas et al., 2015; Cañas et al., 2016; Cañas et al., 2017). The concept map has been widely recognized as a tool for thought (Wheeler & Collins, 2003; Novak & Cañas, 2004, 2008; Green, 2010; Rosen & Tager, 2014; Bixler et al., 2015; Cañas et al., 2016; Cañas et al., 2017; Ghani et al., 2017).

When more information is received through the sharing of information /ideas /concepts, more often cognitive skills such as critical thinking skills are used by the students to meet the demand of active learning processes (Walker, 2003; Cañas, 2004, 2008; Cañas, et al. 2012; Kinchin, 2014; Chang et al., 2016; Ghani et al., 2017). In this research, the CCM students were actively building their concept map throughout the learning process, which indirectly, the critical thinking skills are used more frequently and this we called the training of critical thinking skills. Students who practice and training more on critical thinking skills, will more easily to acquire critical thinking skills (Novak & Gowin, 1984; Novak & Cañas, 2004, 2008; Bixler et al., 2015; Cañas et al., 2017).

Conclusion

The aim of the study is to identify the effectiveness of Collaborative Concept Mapping (CCM) and Individual Concept Mapping (ICM) in improving students' critical thinking skills in Science. The study found that CCM as a teaching approach is effective in fostering students' critical thinking skills in Science compare to ICM and CM teaching approaches. Thus, CCM can be used as an alternative teaching approach in Science classroom to enhance secondary school students' critical thinking skills.

Recommendations

Even though the findings of this study showed the students' critical thinking skills in Science improved by the used of concept mapping especially the collaborative concept mapping, perhaps, this study can be enhanced and further the study by looking into details on the concept map that had been built by the students. For further research, scoring the students' concept map should be a wise option to help researcher to get the detail view on how the concept of knowledge been expended and how its impact the students' critical thinking skills in Science subject.

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