THE EFFECT OF CONCEPT VISUALISATION ON CRITICAL THINKING SKILLS IN SCIENCE LEARNING AMONG MALAYSIAN PRIMARY SCHOOL CHILDREN

LILY PREMALA MICHAEL

ASIA e UNIVERSITY 2023

THE EFFECT OF CONCEPT VISUALISATION ON CRITICAL THINKING SKILLS IN SCIENCE LEARNING AMONG MALAYSIAN PRIMARY SCHOOL CHILDREN

LILY PREMALA MICHAEL

A Thesis Submitted to Asia e University in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

March 2023

ABSTRACT

It was necessary to promote critical thinking skills among students because a lack of critical thinking skills among students had been a persistent drawback in primary science education. According to studies, the idea visual image was used to improve critical thinking skills with some techniques being more practical than others. The study's goal was to determine whether conception mapping (a conception visual image technique) was an effective technique for developing essential thinking ability in science learning among Malaysian primary school children. For this purpose, students using concept mapping were compared to students using mind mapping (the existing visualisation technique). A quasi-experimental methodology was used with a total of seventy students; thirty-five students in the mind map class and the remaining was in the concept map class. The concept map class used concept mapping strategy while the mind map class used mind mapping strategy. The two classes were given a pre-test and a post-test on their science achievement and critical thinking skills. The gain score means for science achievement and critical thinking skill in both groups were compared using independent t-test and descriptive statistics. In learning science, a satisfaction questionnaire and a behavioural checklist were also used to assess students' attitudes and interactions with concept mapping and mind mapping. The data analysis results showed that the gain score means for the concept map class were greater than the gain score means of the mind map class on science achievement as well as critical thinking with p < .05 indicating statistical significance. In addition, students in the concept map class were more positive about the visualisation technique used than students in the mind map class (p < .05). As a result, the findings supported the conclusion that the concept mapping strategy was more effective in improving students' critical thinking skills and science learning. Thus, concept mapping was preferred over mind-mapping as a classroom learning tool for science teaching and learning in primary schools to support science learning and the development of critical thinking skills.

Keywords: Concept mapping, mind mapping, visualisation technique, science learning, critical thinking, satisfaction, interaction, descriptive statistics

APPROVAL

This is to certify that this thesis conforms to acceptable of scholarly presentation and is fully adequate, in quality and scope, for the fulfilment of the requirements for the degree of Doctor of Philosophy

The student has been supervised by: Professor Dr. Maizam Alias

The thesis has been examined and endorsed by:

Associate Professor Dr. Sharipah Ruzaina Syed Aris UiTM Examiner 1

Professor Dr. John Arul Philip AeU Examiner 2

This thesis was submitted to Asia e University and is accepted as fulfilment of the requirements for the degree of Doctor of Philosophy.

Professor Dr Titik Khawa Abdul Rahman Asia e University Chairman, Examination Committee (28 March 2023)

DECLARATION

I hereby declare that the thesis submitted in fulfillment of the PhD degree is my own work and that all contributions from any other persons or sources are properly and duly cited. I further declare that the material has not been submitted either in whole or in part, for a degree at this or any other university. In making this declaration, I understand and acknowledge any breaches in this declaration constitute academic misconduct, which may result in my expulsion from the programme and/or exclusion from the award of the degree.

Name: Lily Premala Michael

Signature of Candidate:

Date: 28 March 2023

Copyright by Asia e University

ACKNOWLEDGEMENTS

First and foremost, I wanted to thank my advisor, Professor Dr. Maizam Alias, for her unwavering support of my PhD studies and related research, as well as her patience, motivation, and vast knowledge. Throughout the research and writing of this thesis, her advise and encouragement were invaluable. I could not have asked for a better advisor and mentor for my PhD studies.

In addition to my advisor, I would like to thank Professor Ts Dr. Titik Khawa Abdul Rahman (Chairman of the Examination Committee), Associate Professor Dr. Sharipah Ruzaina Syed Aris (Examiner 1), Professor Dr. John Arul Phillips (Examiner 2), lecturers, and staffs at Asia e University for all of their facilities, assistance, and advise. Without their invaluable assistance, this study would not be possible.

I would also like to thank my parents, Mr. Gopal Michael and Madam Hasplin anak Jeros, my beloved husband, Mr. Julian anak Akek, and our wonderful children, Christo Christiansen, Christabella Claire, Chriscarlson Carter, and Chrisclarrice Claudia, who endured a lot during my research and whose love, affection, and supplications encouraged me to complete my studies.

Finally, I would like to express my gratitude to my siblings, Sheila Michael, Dr. Syukri Imran @ Gimson Michael, Samson Michael, and Dr. Jacklyn Michael, as well as my friends especially Madam Bibian anak Nicholas, for lighting the candles that lit my path to success. Their years of assistance would undoubtedly be remembered.

TABLE OF CONTENTS

	'RACT	ii
APPR	COVAL PAGE	iii
DECI	LARATION	iv
ACK	NOWLEDGEMENTS	vi
TABI	LE OF CONTENTS	vii
LIST	OF TABLES	X
LIST	OF FIGURES	xii
LIST	OF ABBREVIATIONS	xiii
CHAPTER 1	INTRODUCTION	1
1.0	Background of the Study	3
1.1	Problem Statement	7
1.2	Objectives	13
1.3	Research Questions	13
1.4	Research Hypotheses	14
1.5	Operational Definitions	15
1.6	Justifications and Significance of the Study	17
1.7	Limitation of the Study	18
1.8	Structure of Thesis	19
1.9	Chapter Summary	20
CHAPTER 2	2 REVIEW OF LITERATURE	21
2.0	Introduction	21
2.1	Theoretical Framework	21
	2.1.1 Comparison between Ausubel Learning Theory	23
	and Constructivism Theory	
2.2	Learning Theories and Types of Learning	23
	which related to the underpinning theory of the study	
	2.2.1 Constructivist Learning Theory and Methods	27
	2.2.1.1 Cooperative Learning	30
	2.2.1.2 Learning through Experience	32
2.3	Critical Thinking Concepts and Theories	33
	2.3.1 Definition and Concepts of Critical Thinking	34
	2.3.2 Relationship between Psychology	35
	and Critical Thinking	
2.4	Mind Maps and Mind Mapping: Existing teaching	36
	and learning tool used in primary school science	
	2.4.1 Characteristics of Mind Maps and Steps	38
	of Building MindMaps	
	2.4.2 The Advantages and Disadvantages of	42
	Mind Mapping	
2.5	Concept Maps and Concept Mapping: Teaching and	45
	learning tool to be tested in primary school science	

	2.5.1 Characteristics of Concept Maps	46
	2.5.2 Types of Concept Maps	48
	2.5.3 Use of Concept Mapping in Education	49
	2.5.4 Concept Mapping in the Classroom Setting	52
	2.5.5 Limitation of Concept Mapping	53
	2.5.6 Concept Mapping, Learning and Student Performance	54
	2.5.7 Concept Mapping and Critical Thinking	57
	2.5.8 Concept Mapping, Student Satisfaction	59
	and Interaction	
2.6	Concept Mapping and Meaningful Learning	62
	2.6.1 Ausubel's Meaningful Learning Theory	63
	2.6.2 Advantages of Meaningful Learning	64
	2.6.3 Concept Mapping, Meaningful Learning and	65
	Critical Thinking	
2.7	Conceptual Framework	66
2.8	Chapter Summary	68
CHAPTER	3 METHODOLOGY	69
3.0	Introduction	69
3.1	Research Design	69
3.2	Population and Sampling	71
3.3	Instrumentation	74
3.4	Validity and Reliability	81
3.5	Data Collection Procedure	84
3.6	Pilot Study	90
3.7	Chapter Summary	94
CHAPTER	4 ANALYSIS AND FINDINGS	95
4.0	Introductions	95
4.1	Normality test for the concept map and mind map class	ses 95
4.2	Effect of concept mapping and mind mapping on scient achievement	ce 97
4.3	Effect of concept mapping and mind mapping on critication thinking skills	al 100
4.4	Effect of concept mapping and mind mapping on learning	ing 103
	satisfaction	105
	4.4.1 Students' satisfaction differences in	107
	learning science between the concept map and	
	mind map classes	
4.5	Effect of concept mapping and mind mapping on stude	nts' 108
1.6	interaction	111
4.6	Discussion of Findings	111
	4.6.1 Research Question 1: Effect of concept	111
	mapping on science achievement4.6.2 Research Question 2: Effect of concept mappir	ng 11 <i>6</i>
	4.6.2 Research Question 2: Effect of concept mappir on critical thinking	ng 116
	4.6.3 Research Question 3: Satisfaction of students	121
		viii

	4.6.4	Research Question 4: Learning interaction and conceptmapping	124
4.7	Chapte	er summary	126
CHAPTER 5		ONCLUSION, IMPLICATION AND COMMENDATIONS	128
5.0	Introd	uction	128
5.1	Conclu	usion	128
5.2	Limita	tion of the Study	131
5.3	Implic	ations of the Study	132
5.4	Recon	nmendation for Future Research	137
5.5	Chapte	er Summary	138
REFERENCI	ES		139
APPENDICE	S		165
Append	dix A:	Examples of mind maps used by students in learning science	165
Append	dix B:	Examples of reasoning items from the Year 6 science critical thinking test	166
Appene	dix C:	Examples of Science Achievement Test Paper 1	167
Appene	dix D:	Examples of Science Achievement Test Paper 2	170
Appene	dix E:	Student Engagement Observation Checklist	173
Appene	dix F:	Satisfaction questionnaire for the mind map class	174
Appene	dix G:	Satisfaction questionnaire for the concept map class	177
Appene	dix H:	A sample of lesson plan to construct a concept map	180
Appene	dix I:	Samples of Year 4 science lesson plans	181

LIST OF TABLES

Table		Page
2.1	Comparison between Ausubel Learning Theory and	23
	Constructivism Theory	
2.2	Cognitive and social constructivism characteristics	28
2.3	Mind Maps and Concept Maps: What's the Difference?	48
3.1	The number of students and genders for the mind map	74
	and concept map classes	
3.2	Number of items according to the cognitive domains for	77
	science achievement tests (Paper 1 and Paper 2)	
3.3	Number of items for each type of behaviour in the student	80
	engagement observation checklist	
3.4	Year 4 Science Topics taught in the current study	87
3.5	Cronbach's Alpha coefficient and its interpretation	92
3.6	Science critical thinking test results for the concept map	93
	and mind map classes	
3.7	Science achievement test results for the concept map and	93
	mind map classes	

х

4.1	Shapiro-Wilk normality test for the concept map class	96
	science achievement test	
4.2	Shapiro-Wilk normality test for the mind map class science	96
	achievement test	
4.3	Shapiro-Wilk normality test for the concept map class	96
	science critical thinking test	
4.4	Shapiro-Wilk normality test for the mind map class science	97
	critical thinking test	
4.5	Descriptive statistics and independent t-test science	98
	achievement pre-test results for the concept map and mind	
	map classes	
4.6	Descriptive statistics and independent t-test science	98
	achievement post-test results for the concept map and mind	
	map classes	
4.7	Comparing reasoning items Paper 1 and Paper 2 science	99
	achievement post-test results for the concept map and mind	
	map classes	

4.8	Descriptive statistics and independent t-test science critical	101
	thinking pre-test results for the concept map and mind map	
	classes	
4.9	Descriptive statistics and independent t-test science critical	102
	thinking post-test results for the concept map and mind	
	map classes	
4.10	Comparing reasoning items science critical thinking post-	102
	test results for the concept map and mind map classes	
4.11	Descriptive statistics on students' satisfaction towards the	104
	use of concept mapping in learning science	
4.12	Descriptive statistics on students' satisfaction towards the	106
	use of mind mapping in learning science	
4.13	Descriptive statistics students' satisfaction results for the	107
	concept map and mind map classes	
4.14	Descriptive statistics students' positive interaction results	109
	for the concept map and mind map classes	
4.15	Descriptive statistics students' negative interaction results	110
	for the concept map and mind map classes	

LIST OF FIGURES

Figure		Page
2.1	Concept map of constructivism	26
2.2	A diagram of ZPD and scaffolding	29
2.3	Mind Map module	39
2.4	A mind map example and its applications	41
2.5	Concept Map	47
2.6	Examples of (a) Hierarchical Concept Mapping, (b) Flow	49
	Chart, (c) Spider Concept Mapping, and (4) System Mapping	
2.7	Concept Mapping in the classroom by students	53
2.8	Concept Maps	56
2.9	Teaching For Meaningful Learning	64
2.10	A visual representation of Ausubel's theory	66
2.11	Depicted the study's conceptual framework	67
3.1	The research procedure of the study	89

LIST OF ABBREVIATION

ANOVA	Analysis of Variance
ВРК	Curriculum Development Section
СМ	Concept Map
CTS	Critical Thinking Skills
DSKP	Curriculum Standard and Assessment Document
DV	Dependent Variable
FPK	National Education Philosophy
IV	Independent Variable
KBSR	Integrated Curriculum for Primary School
KSSR	Primary School Standard Curriculum
MOE	Malaysian Ministry of Education
MM	Mind Map
PBL	Problem-based Learning
UPSR	Primary School Achievement Test

CHAPTER 1

INTRODUCTION

The economic development and expansion of a country (or nation) were significantly influenced by education (Permani, 2009). Governments of developing countries were undertaking huge expenditure on the improvement of the education sector as it was believed that the knowledge imparted to the children in classrooms was a determinant for high standard of living, improved stability, and future growth of the respective developing countries (Odit, Dookhan and Fauzel, 2010). Therefore, the target group that was essential to a country's growth was students in all types of educational institutions, whether at the primary, secondary, or higher levels (Bhardwaj, 2016). These students were tasked with carrying out the nation's (or the country's) aim of encouraging high standards of education among the students (Hanushek and Wößmann, 2007).

The knowledge, abilities, and competencies possessed by younger generations (or the students) were critical to a country's success in the face of international economic rivalry (Bhardwaj, 2016). Higher level thinking skills which call for students (or learners) to analyse, evaluate, and create (the skills that demanded students to think critically) were particularly important for these young generations as these skills would enable the young generations to think strategically (or having a proactive planning) and put their theories into practise for the benefit or advantage of the nation (Odit, Dookhan and Fauzel, 2010).

Critical thinking skills were crucial to higher level thinking skills and it differentiated the skills of critical thinking from the lower level thinking skills. Lower level thinking skills only included (or consisted) basic skills liked remembering, understanding, and applying (Bloom's Taxonomy: Cognitive Domains). Meanwhile, the three highest levels in Bloom's Taxonomy (analysis, synthesis, and evaluation) were frequently said to represent critical thinking (Lai, 2011). The components of critical thinking which included analysing, reasoning, evaluating, problem solving, and decision making (Saiz and Rivas, 2008) would enable students to analyse arguments, making inferences using reasoning, to evaluate information and forming opinion, and performing problem-solving and decision-making more effectively or constructively (Lai, 2011; Snyder and Snyder, 2008).

Acquiring or gaining the skills of critical thinking (Malaysian Ministry of Education [MOE], 2013) was crucial (or significant) as the world was becoming more complex and sophisticated (Uribe-Enciso, Enciso and Daza, 2017). The rapid changes and development in recent times were exposing individuals to various challenges which required important skills and expertise such as critical thinking for making effective decisions. For example, the popularity of mass media and the explosion of information from networking sites were confusing the students with a range of information. As a result, confronting the challenges posed by the complexity of daily life necessitates not only extensive knowledge but also the ability to apply that knowledge in a variety of situations. For this purpose (or reason), students should be taught critical thinking skills and how to analyse information before applying the skills in their daily lives (Tayyeb, 2013). Giam and Duke (2003) suggested that critical thinking was essential (or absolutely necessary) to form citizens who knew and were able to use their minds in the face of adversity, stress, and changes. Therefore, it was crucial for the Malaysian Ministry of Education (MOE) to produce students who could think critically besides capability of meeting the aspirations and wishes of their family, society, and country (Zhaffar, Hamzah and Razak, 2017). This was stated in the Malaysian National Education Philosophy where one of the

aspirations for students was to improve the skills of thinking (Viera, Viera and Martin, 2011).

Critical thinking abilities (or the skills of critical thinking) and to put knowledge into practise appropriately required a person to have a deep understanding of concepts (Nappi, 2017; Mitrevski and Zajkov, 2011) that were foundational to the issue being addressed. Thus, meaningful understandings of concepts was necessary (Agra, Formiga, Oliveira, Costa, Fernandes and Nóbrega, 2019) for a person to judge and to evaluate propositions as concepts form the basis of propositions (Kinchin, Möllits and Reiska, 2019). For this reason, several teaching and learning tools had been proposed to help the understandings of concepts in the form of visual depictions and diagrams such as mind mapping (Davies, 2011) and concept mapping (Beavers, 2014; Liu, Zhao, Ma and Bo, 2014; Whiting and Sines, 2012).

1.0 Background of the Study

To better meet the needs of learners (or students) to develop greater thinking skills especially the skills of critical thinking, Malaysia's primary education system had been transformed from the old primary school syllabus (Integrated Curriculum for Primary School, 1983) to the new primary school syllabus (Primary School Standard Curriculum, 2011). The transformation was based on the 1983 integrated approach and improvements had been made in the 2011 new primary school syllabus (Shan, Yunus, Mohamad and Malaysia, 2016).

Compared to the old primary school syllabus which only focused on three main skills (reading, writing, and counting), the new primary school syllabus focused on four skills namely reading, writing, counting, and reasoning (Malaysian Ministry of Education [MOE], 2013). The new transformation emphasised reasoning skills which was one of the components of critical thinking, in order to go after the

advancement of consideration, technology, economics, and globalisation (Curriculum Development Division, 2012). The new curriculum empowered students as well as the teachers, and enriched the students and the teachers with the capabilities to increase their thinking, thus gave them more room and freedom to exercise their creativity (Malaysian Education Blueprint, 2013-2025; Malaysian Ministry of Education [MOE], 2013). This was supported by Noraini and Khairul (2014) that Malaysian education aimed to develop students' critical, creative, and collaborative thinking abilities and potential.

As a result, reasoning skills (which went hand-in hand with critical thinking and was also one of the key components of the critical thinking besides creative thinking, decision making, and problem solving) were expected to enable students to provide a causal and rational logic state in ordered to solve any problems (or come to conclusions), to understand the learning process, to differentiate between the good and the bad, and to understand the cause and effect of events, things, or conditions (Aziz, Shamsuri and Damayanti, 2013). A student who was good at reasoning possessed the following characteristics: (1) bold and wise in asking questions, (2) critical in thinking, creative, and innovative, (3) curiosity, (4) displayed flexible thinking, (5) willing to work together (group tasks/activities), (6) risk takers, (7) had foresight, and (8) were able to make comparison (Curriculum Development Division, 2012).

Meanwhile, higher level thinking skills (the skills that went beyond basic observation of facts and memorisation which also the skills of critical thinking) was one of the important elements emphasised in the Malaysian primary education (Malaysian Education Blueprint, 2013-2025; Sulaiman, Muniyan, Madhvan, Hassan, Syrene and Rahim, 2017) and students were expected to apply their knowledge, skills, and values for reasoning and reflection at the higher levels of Bloom's Taxonomy of Cognitive Domains (Malaysian Ministry of Education [MOE], 2013; Chun and Abdullah, 2019). Higher level thinking skills occurred when a person took new information, and the previously stored information in the memory and interrelated, rearranged, and extended this information in order to find possible answers in perplexing situations. This was in line with what proposed by David Ausubel that students associated new information with relevant concepts already present in their cognitive structure. Therefore, to encourage the application of higher level thinking skills in students and also to demonstrate students' critical thinking skills, a newer approach (or method/strategy) was required for better teaching and learning as suggested by Smith (2014).

Therefore, as emphasised by the Malaysian Ministry of Education (MOE) to develop students' critical thinking skills, problem-based learning was one of the approaches that had been implemented in the teaching and learning process to achieve this goal (Malaysian Ministry of Education [MOE], 2013). Through problem-based learning, students were expected to achieve specific learning to make them competent and capable besides having the opportunity to demonstrate problem-solving and reasoning, thus improving critical thinking skills as suggested by Ram, Ram and Sprague (2009), Makin (2016) and Kurniawati (2019).

Problem-based learning had been introduced in primary school science and this approach was applied by teachers in the classroom to promote students' critical thinking and also to strengthens students' skills of reasoning (Curriculum Development Division, 2012 and Lai 2011). Students worked in small groups; three to five students per group (Malaysian Ministry of Education [MOE], 2013; Curriculum Development Division, 2012) on real world problems (or real situations), and students were given the opportunity to identify the ideas and skills required to solve the problems they faced (or confronted) (Sulaiman, Muniyan, Madhvan, Hassan, Syrene and Rahim, 2017).

In Malaysia primary school's curriculum, subject of science helped students to develop the skills of critical thinking and creative thinking about life in general (Aziz, Shamsuri and Damayanti, 2013). Through learning science, students were expected to improve, and to develop their scientific and critical thinking abilities (or critical thinking skills) as mentioned by Mataniari, Willison, Effendi Hasibuan, Sulistiyo and Dewi (2020). However, the development of scientific and thinking skills were dependent on the approaches and tools used (or applied) in science teaching and learning (Kurniawati, 2019). The method of lecturing (or lecture method), however, would not achieve such learning goals when learning science and this was supported by Kurniawati (2019) that lecture method would not improved the students' thinking skills and the learning process only reached the level of memorising (which was one of the lower level thinking components).

In addition to the problem-based learning approach, teachers and students must used or applied mind maps in their teaching and learning to improve critical thinking skills (Malaysian Ministry of Education [MOE], 2013; Curriculum Development Division, 2012). As suggested by Adodo (2013), students who used mind mapping were expected to be able to think critically, to solve problems, became more creative, and be accountable for their own learning. Thus, mind mapping as proposed by Tony Buzan in the 1960s was introduced in the Malaysia Innovative Thinking program (National Education Blueprint, 2013-2025) which was expected to enhance and to develop critical thinking skills among students. This teaching and learning tool was defined by Eppler (2006) as a multi-colored and image-centered

radial diagram that represented semantic or other hierarchical connections between portions of learned material. In science class, teachers and students used mind maps within problem-based learning in finding solutions to a problem or a situation (Hmelo-Silver, 2004). Thus, the combination of problem-based learning and mind maps in teaching and learning science was expected to be effective (or successful) in developing students to think critically as they used their imagination and explored associations between science concepts (Davies, 2011).

1.1 Problem Statement

Despite the application (or implementation) of mind mapping within problem-based learning in Malaysia primary school science, the students were still weak in critical thinking as demonstrated by their science standard examination results in the 2016 Malaysian Primary School Achievement Test (Panduan Malaysia, 2016) that indicated lack of higher level thinking skills in general and critical thinking in particular. Of the total 440,514 candidates who sat for the Malaysian Primary School Science Achievement Test, only 6.9% obtained A. In fact, this subject showed the lowest numbers of As compared to other core subjects such as the Malay Language, English Language, and Mathematics (Panduan Malaysia, Table 2 and Table 3, 2016).

From the Malaysian Primary School Achievement Test 2016 results analysis, the results showed that the candidates (or the students) were having difficulties with the new format in the test (Panduan Malaysia, 2016) as the new constructs tested consisted of critical thinking elements (National Education Blueprint, 2013-2025). In fact, as much as 40% of the questions assessed in the examination were higher level thinking items (as required by the Malaysian Ministry of Education [MOE], 2013) which also consisted reasoning items (which demanded students to think critically and also emphasised in the new primary school syllabus) compared with the old Malaysian Primary School Achievement Test format which had no critical thinking items or reasoning items (Rajaendram, 2015). Students lacked of critical thinking skills may be due to a lack of meaningful understanding of concepts that were required for the development of higher level thinking skills (Robinson, Dailey, Hughes and Cotabish, 2014; Saido, Siraj, Nordin and Al-Amedy, 2017). This also could possibly be because students' learning methodologies (or strategies) did not allow them to construct appropriate understanding of fundamental science concepts. As a result, students demonstrated a negative attitude, a loss of interest, and a lack of concentration in class, resulting in low performance in public tests.

Components of critical thinking required appropriate selections and applications of concepts which depended on a person's understanding of the associated concepts (Dixon and Brown, 2012). Mind maps, as Eppler (2006) pointed out, did not support the development of meaningful understandings of concepts because mind maps did not show systematic relationships among sub-concepts relating to one concept which implied that students were not required to think critically when providing or constructing mind maps. Mind mappers only needed (or required) to generate related concepts to a main concept but did not need to propose and evaluated the specific relationships between these concepts (Martin, 2011). Thus, producing a mind map did not trigger the need for students to evaluate and to judge which were important aspects of critical thinking skills.

On the other hand, creating or constructing a concept map demanded that student who drew the maps proposed and evaluated connections between concepts (here students were required to think critically) in addition to generating multiple associated concepts (Soika, Reiska and Mikser, 2014). In short, concept mappings (activity of drawing concept maps) forced student who drew it to generate and to

8

evaluate their ideas which were crucial or very important to the advancement (or development) of critical thinking skills. In comparison to mind mappings, concept mapping was expected to be a potentially effective learning tool for improving children's learning and achievement in science, and critical thinking based on the nature of concept maps and the process of generating concept maps.

Previous studies using concept mapping in primary science had shown that concept mapping able to improve children's learning and also developed children's critical thinking skills. Çömek, Akınoğlu, Elmacı and Gündoğdu (2016) reported in their studies that concept mapping strategy helped students to improve their critical thinking abilities in primary science education. Meanwhile, a study conducted by Qarareh (2010) reported that students using concept mapping showed greater effect on academic achievement in primary science. The results were also supported by Ling and Boo (2007) that the use of concept mapping could enhance the learning and understanding of science concept among students. According to Ling and Boo (2007), students who applied concept mapping in their studies performed better as opposed to those who were not. This indicated that concept mapping was a better and more effective learning tool for improving students' learning and ability to think critically. Previous study had also revealed that concept mapping could help primary school students to develop their critical thinking abilities and science learning skills, and there was a strong possibility that similar findings would be found in the current study. However, similar findings could not be assumed to be found in all populations as the context of studies differ with respect to attributes of study population, culture, and learning context which may resulted in greater or lesser effect size and academic significance.