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Contents

The Acquisition of Logical Thinking Abilities among Rural Secondary Students of Sabah

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ABSTRACT

The science curriculum in Malaysia emphasizes the acquisition of scientific skills, thinking skills, and the inculcation of scientific attitudes and noble values. Besides that, the acquisition of scientific and technological knowledge and its application to the natural phenomena and students' daily experiences are also equally emphasized. The purpose of this study was to gauge the acquisition of logical thinking abilities, namely, conservational reasoning, proportional reasoning, controlling variables, combinatorial reasoning, probabilistic reasoning, and correlational reasoning among Form 4 students in the Interior Division of Sabah, Malaysia. This study was also aimed to ascertain if there is any significant difference in students' acquisition of logical thinking abilities based on students' gender and science achievement at lower secondary level. This was a non-experimental quantitative research and sample survey method was used to collect data. In this study, samples were selected by using a two-stage cluster random sampling technique. Independent sample t-test and one-way ANOVA were used to test the stated null hypotheses at a predetermined significance level, α = .05. Research findings showed that rural secondary students' acquisition of logical thinking abilities was low. The average item mean for all the subscales, except conservational reasoning, were lower than the overall average item mean. This research also surprisingly revealed that up to 98 percent of the respondents were categorized at the concrete operational stage whereas only 2 percent were categorized at the transitional stage. This study also found no significant difference in the mean of logical thinking abilities, except conservational reasoning, based on students' gender, but a significant difference based on students' science achievement at lower secondary level was found. These research findings bring some meaningful implications to those who are involved directly or indirectly in the development and implementation of secondary science curriculum, especially at the rural secondary schools of Sabah, Malaysia.

Keywords: Combinatorial reasoning, conservational reasoning, controlling variables, correlational reasoning, logical thinking abilities, probabilistic reasoning, proportional reasoning

BACKGROUND OF THE STUDY

The development of thinking abilities is well discussed in the world of education. Cohen (1980) stated that the higher the ability of a person to think in an abstract way, the higher the ability of the person will function effectively in the society. Hence, the improvement of formal reasoning and thinking abilities among students is one of the aims of science education at all levels of schooling.

Cognitive Development Theory, a wellknown theory proposed by Jean Piaget has conceptualized four different stages in the cognitive development of a person i.e. sensory motor (0 - 2 years), preoperational

(2 - 7 years), concrete operational (7 - 11 years), and formal operational (11 - 16 years). The main difference among these stages of cognitive development is the mode of thinking involved. Children at formal operational stage can think logically about abstract propositions and test hypotheses systematically. At the same time, they become concerned with the hypothetical, the future, and ideological problems. Researchers (e.g., Inhelder and Piaget, 1958; Lawson, 1982b: 1985; Linn, 1982) had identified five different modes of formal operational reasoning i.e., proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning which are determinants of students' success in advanced science and mathematics courses at secondary level (Wilson and Wilson, 1984).

PROBLEM STATEMENT

The fundamental function of the schooling system in the United States of America was outlined by the Educational Policies Commission in 1961. The Commission stressed the importance of logical thinking abilities in education as stipulated by the following statement:

The purpose which runs through and strengthens all other educational purposes - the common thread of education is the development of the ability to think. (Renner and Philips, 1980, p.193)

Renner and Philips (1980) strongly believed that students should be given opportunities to develop their thinking abilities as a base for intellectual development. In relation to this, Lawson (1985) stressed that schooling system is not meant for the teaching of facts and concepts which are specific to a particular domain but more importantly to assist students in acquiring thinking skills.

As stipulated in the Integrated Curriculum for Secondary School (ICSS) science curriculum, the aims of the science curriculum in Malaysia are to provide students with the knowledge and skills in the science and technology and enable them to solve problems and make decisions in everyday life based on scientific attitudes and noble values. Via the science curriculum, it is hoped that students will be able to acquire scientific skills (i.e., science process skills and science manipulative skills), thinking skills creative and critical thinking skills), and apply knowledge and skills in a creative and critical manner for problem solving and decisionmaking (Pusat Perkembangan Kurikulum, Kementerian Pelajaran Malaysia, 2001).

Based on the Cognitive Development Theory proposed by Jean Piaget, Malaysian Form 4 students are at the formal operational stage whereby they can think logically about abstract propositions and test hypotheses systematically. At the same time, they also become concerned with the hypothetical, the future and ideological problems. As pointed out by Wilson and Wilson (1984), formal operational reasoning was determinant of students' success in advanced science and mathematics courses at secondary level.

Previous researchers (e.g., DeLuca, 1981; Hernandez, Marek and Renner, 1984; Howe and Shayer, 1981; Meehan, 1984; Shemesh, 1990) had found a significant difference in logical thinking abilities between male and female students. Male students have shown better performance in Piagetian formal reasoning tasks as compared to their counterparts. However, other researchers did not find any significant difference (e.g., Keig and Rubba, 1993; Michael Liau, 1982; Roadrangka, 1995). On the other hand, previous researches (e.g., Bitner, 1991; Roadrangka, 1995; Siti Hawa Munji, 1998) suggested that formal reasoning abilities are closely related to science achievement.

However, there are not many researches conducted to gauge secondary students' logical thinking abilities, especially in the Malaysian rural secondary schools context. Hence, due to the scarcity of research in this area, the main aim of this study is to gauge the logical thinking abilities among Form 4 students in the Interior Division of Sabah, Malaysia. This study is also aimed to identify if there is any significant difference in rural students' logical thinking abilities based on their gender and science achievement at lower secondary level.

RESEARCH OBJECTIVES

The objectives of this study are:

1. To gauge the logical thinking abilities among Form 4 students in the Interior Division of Sabah, Malaysia.
2. To investigate if there is any significant difference in rural secondary students' logical thinking abilities based on their gender and science achievement at lower secondary level.

RESEARCH HYPOTHESES

This study was guided by the following hypotheses:

Ho1 : There is no significant difference in the acquisition of logical thinking abilities based on students' gender.

Ho2 :There is no significant difference in the acquisition of logical thinking abilities based on students' science achievement at lower secondary level.

RESEARCH DESIGN

This was a non-experimental quantitative research and a sample survey method was used to collect data. The samples were selected by using a two-stage cluster random sampling technique. Univariate analysis which includes independent sample t-test and One-way Analysis of Variance (ANOVA) were used to test the stated null hypotheses at a predetermined significance level of .05.

CONTEXT OF THE STUDY

This study was conducted in 18 Form 4 classes from nine secondary schools in the Interior Division of Sabah, Malaysia. The distribution of schools and Form 4 classes according to four districts in the Interior Division of Sabah, Malaysia is shown in Table 1.

POPULATION AND SAMPLING

The population of this study was Form 4 students, from 22 secondary schools in the Interior Division of Sabah, who took the Integrated Curriculum for Secondary School (ICSS) Science as one of their compulsory learning subjects in school. Population size is approximately 3,500 students. The average age of the population is 16 years old. Sample size of this study was determined based on the formula suggested by Krejcie and Morgan (1970) and power analysis (Miles and Shevlin, 2001). Krejcie and Morgan suggested that for a

TABLE 1

Distribution of schools and Form 4 classes according to four districts in the interior division of Sabah, Malaysia

District	No. of schools	No. of Form 4 classes
Tambunan	2	4
Keningau	4	8
Tenom	2	4
Nabawan	1	2
Total	9	18

population between 3,000 and 3,500, a minimum sample size of 341-346 is acceptable. Thus, the sample size of this study is adequate compared to Krejcie and Morgan's recommendation.

To be specific, two-stage cluster random sampling was used to identify schools and Form 4 classes to be involved in this study. At stage one, systematic sampling was used to identify nine secondary schools from four districts in the Interior Division of Sabah, Malaysia. Once the schools have been chosen, simple random sampling method was used to select any two Form 4 classes from each chosen school by using the random number table. All the students in the chosen classes were automatically taken as samples of the study. The combination of sampling techniques is to ensure the representativeness of the samples used in the study.

RESEARCH INSTRUMENT

Group Assessment of Logical Thinking (GALT) is a paper-and-pencil test which consists of 21 items to measure students' logical thinking abilities. The distribution of items according to six different modes of logical thinking abilities is shown in Table 2.

Instrument used in this study is a modified and translated Malay version from the instruments i.e. 'Group Assessment of Logical Thinking' (GALT) (Roadrangka et al., 1983) and 'Test of Logical Thinking' (TOLT) (Tobin and Capie, 1981). These instruments were developed to measure students' modes of Piagetian cognitive reasoning abilities i.e. conservational reasoning, proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning. Double-multiple-choice response format for alternatives and justifications of answers were used in this instrument. Students were posed with a problem and asked to choose the best answer, from 2 to 5 possible answers available, for each problem. Following that, students were asked to choose the best justification for the chosen answer from a list of 2 to 5 possible justifications. On the other hand, pictorial presentation was used to enhance students' better understanding of the items (Roadrangka et al., 1983).

Validity and Reliability of the Instrument

The researcher had examined all the items in the original GALT and TOLT instrument and found that most of the items were suitable to be used in the Malaysian context. Efforts have been devoted to ensure the content and face validity of the modified and translated version of the instrument. In this matter, all the items were translated into Malay language so that the respondents can understand the items and choose their best answers and justifications without any semantic distortion. The Cronbach's alpha reliability coefficient of the instrument was found at .52 which is considered moderate for its use in the study.

TABLE 2

Distribution of GALT items according to six different modes of logical thinking

Subscales	Item	No. of items
Conservational reasoning	1,2,3,4	4
Proportional reasoning	5,6,7,8,9	5
Controlling variables	10,11,12	3
Probabilistic reasoning	13,14,15	3
Correlational reasoning	16,17,18	3
Combinatorial reasoning	19, 20, 21	3
Total		21

DATA COLLECTION

Before administering the instrument, formal permission from the school principals involved was sought and obtained. The instrument was then administered by the researcher. Students were gathered in the school hall and the instrument was administered to the students concurrently. The students were told about the nature of the instrument and how the instrument should be answered. The students were given ample time of approximately 2 hours to answer all the questions in the instrument.

DATAANALYSIS

Students' answers on the instrument were checked and scored by the researcher to ensure consistency in the scoring. There were two answers for the first 18 items in the instrument. One point will be given for both correct answers. If only part of the answers is correct, zero point will be given. The last three items in the instrument were used to gauge students' combinatorial reasoning ability. One point will be awarded if all the correct combinations of answers are listed in the space provided. Likewise, zero point will be given if only part of the answers is correct. Possible minimum score for this instrument is zero whereas the maximum score can reach 21. According to Lawson (1995), students' performance in GALT instrument can be used to categorize students into empiricalinductive thinking pattern (score 0 to 15) or hypothetical-deductive thinking pattern (score 16 to 21). On the other hand, students can also be categorized into three levels of cognitive development i.e. concrete operational (score 0 to 8), transitional operational (score 9 to 15), and formal operational (score 16 to 21) stage.

Descriptive statistics which include measures of central tendency (mean, average item mean) and measures of variability (range, standard deviation, and average item standard deviation) were used to gauge the acquisition of logical thinking abilities among Form 4 students in the Interior Division of Sabah, Malaysia. After the assumptions of using parametric tests were met, univariate analysis such as independent sample t-test and one-way ANOVA were used to test the stated null hypotheses at a specified significance level, $\alpha = .05$.

Independent Sample t-Test

Independent sample t-test was used to determine if there is any significant difference in the acquisition of logical thinking abilities based on students' gender. Independent sample t-test was used to compare the overall mean of logical thinking abilities as well as the scale mean of logical thinking abilities i.e. conservational reasoning, proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning.

One-way Analysis of Variance

One-way ANOVA was used to ascertain if there is any significant difference in the acquisition of logical thinking abilities based on students' science achievement at lower secondary level (low, medium, high). One-way ANOVA was used to compare the overall mean of logical thinking abilities as well as the scale mean of logical thinking abilities. If there is a significant difference, Post-Hoc multiple comparison test i.e., Tukey's HSD (Honestly Significant Difference) will be used to identify which levels of science achievement show significant difference in terms of logical thinking abilities.

RESEARCH FINDINGS AND DISCUSSIONS

Logical Thinking Abilities among Rural Secondary Students

Table 3 shows the overall mean and standard deviation of logical thinking abilities among Form 4 students in the Interior Division of Sabah, Malaysia.

Descriptive statistics in Table 3 and Fig. 1 showed that the overall mean of logical thinking abilities among Form 4 students in the Interior Division of Sabah is 3.191 (average item mean = .152) with a standard deviation of 2.158 (average item SD = .103). The average item mean

TABLE 3

Mean and standard deviation of logical thinking abilities (n = 549)

Subscales	No. of items	Mean	SD	Average item mean[a]	Average Item SD	Range
Conservational reasoning	4	1.384	1.084	.346	.271	0 - 4
Combinatorial reasoning	3	.424	.619	.141	.206	0 - 3
Controlling variables	3	.368	.582	.123	.194	0 - 3
Correlational reasoning	3	.330	.582	.110	.194	0 - 3
Proportional reasoning	5	.516	.749	.103	.150	0 - 4
Probabilistic reasoning	3	.169	.463	.056	.154	0 - 3
Overall	21	3.191	2.158	.152	.103	0 - 12

aAverage item mean = Scale mean divided by the number of items in each scale

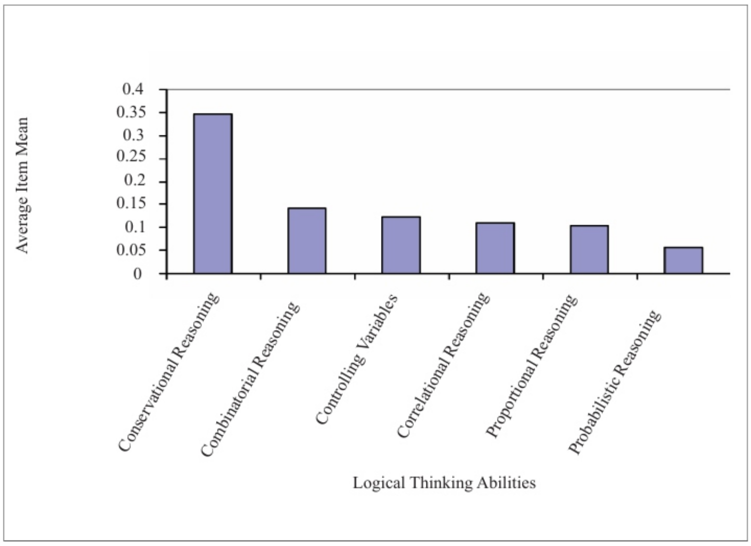

Fig. 1: Average Item Mean of Logical Thinking Abilities (n=549)

according to different modes of logical thinking abilities in descending order are: conservational reasoning (average item mean = .346, average item SD = .271), combinatorial reasoning (average item mean = .141, average item SD = .206), controlling variables (average item mean = .123, average item SD = .194), correlational reasoning (average item mean = .110, average item SD = .194), proportional reasoning (average item mean = .103, average item SD = .150), and probabilistic reasoning (average item mean = .056, average item SD = .154).

These research findings revealed that the acquisition of logical thinking abilities among Form 4 students in the Interior Division of Sabah was low with the average item mean in the range of .056 to .346. Average item mean for all the subscales (except conservational reasoning) were lower than the overall average item mean of logical thinking abilities. Further analysis, based on Lawson's categorization of cognitive development, surprisingly found that 98 percent of the respondents are categorized at the concrete operational stage whereas only 2 percent are categorized at the transitional operational stage. According to Lawson (1995), students can be categorized into three levels of cognitive development i.e. concrete operational, transitional operational, and formal operational based on their performance in GALT instrument.

As shown in Table 3, average item mean according to different modes of logical thinking in descending order are conservational reasoning, combinatorial reasoning, controlling variables, correlational reasoning, proportional reasoning, and probabilistic reasoning. This finding was supported by a model of hierarchical relationships between Piagetian modes of cognitive reasoning and integrated science process skills as proposed by Yap (1985) and Yeany et al. (1986). In the proposed model, probabilistic reasoning is situated at a higher hierarchy as compared to proportional reasoning, controlling variables, combinatorial reasoning, and conservational reasoning which are placed at a lower hierarchy of the model.

Students' low logical thinking abilities might be due to the education system which is more examination-oriented. Hence, less emphasis is given to the teaching and use of logical thinking skills. Science teaching and learning strategies are aligned to objectivism with the aim to cover the syllabus within the allotted time without 'investing' adequate time to nurture thinking skills among students. Furthermore, school evaluation system which only emphasizes the acquisition of content knowledge could contribute to low logical thinking abilities among students. Syed Anwar Aly and Merza Abbas (2000) reported that the evaluation of students' science achievement does not give equal emphasis on the process and product component of scientific skills. Almost 100 percent of the evaluation focused on the science product component i.e., concepts, theories, and formulae. Hence, high achievers in science are students who can explain the related concepts and theories and solve routine problems by using related formulae.

In relation to this, logical thinking abilities among students in local higher learning institutions were also reported as low. Syed Anwar Aly (2000) found that only 19 percent of matriculation college students possess high scientific reasoning abilities, 66 percent at medium stage whereas 15 percent possess low scientific reasoning abilities. In the same study, Syed Anwar Aly (2000) reported that only 19 percent of Malaysian students with average age of 19 years old possess high scientific reasoning abilities as compared to 22 percent of American students with average age of 16 years old.

Mean Difference in the Acquisition of Logical Thinking Abilities based on Students' Gender

Independent sample t-test results (Table 4 and Fig. 2) showed that there is no significant difference in the overall mean of logical thinking abilities based on students' gender (t = -1.721, df = 483.410, p = .086). Thus, the first null hypothesis which stated that there is no significant difference in the acquisition of logical thinking abilities based on students' gender is failed to be rejected.

Although male students (M = 3.367, SD = 2.373) scored higher than female students

TABLE 4

Independent sample t-test results for mean difference in logical thinking abilities based on gender (n = 549)

Subscales	Gender	n	Mean	SD	Mean difference	Effect size	t	df	p
Conservational reasoning	Male	251	1.498	1.201	.209	.193	-2.222*	477.331	.027
	Female	298	1.289	.966					
	Overall	549	1.384	1.084					
Proportional reasoning	Male	251	.582	.777	.122	.163	-1.893	515.368	.059
	Female	298	.460	.720					
	Overall	549	.516	.749					
Controlling variables	Male	251	.387	.612	.035	.060	-.684	547	.495
	Female	298	.352	.557					
	Overall	549	.368	.582					
Combinatorial reasoning	Male	251	.398	.601	-.048	-.078	.903	547	.367
	Female	298	.446	.635					
	Overall	549	.424	.619					

Overall	Male	251	3.367	2.373	.323	.150	-1.721	483.410	.086
	Female	298	3.044	1.949					
	Overall	549	3.191	2.158					

* p < .05
The effect size is the mean difference divided by the pooled standard deviation

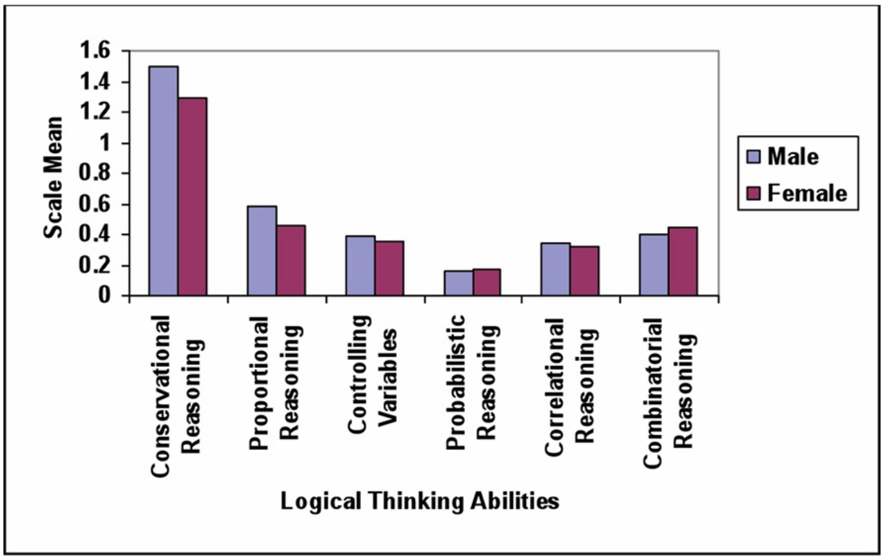

Fig. 2: Mean difference in logical thinking abilities based on gender (n = 549)

(M = 3.044, SD = 1.949), but at t = -1.721 and p = .086, the mean difference is insignificant. However, further analysis showed that male students (M = 1.498, SD = 1.201) scored significantly higher than female students (M = 1.289, SD = .966) in conservational reasoning at t = -2.222, df = 477.331 and p = .027.

The finding of this study also surprisingly revealed that up to 97.2 percent of male respondents and 98.7 percent of female respondents are categorized at concrete operational stage whereas the remaining are categorized at transitional operational stage. Hence, there is no significant difference in the acquisition of logical thinking abilities based on gender. This finding was found to be consistent with the findings of Keig and Rubba (1993), Michael Liau (1982), and Roadrangka (1995). As an example, Michael Liau (1982), in his research to investigate primary school students' ability in conservation of length via three Piagetian experiments, he found that there is no significant difference in the ability of conservation of length between male and female students. However, this finding was contradicting with previous researchers (DeLuca, 1981; Hernandez, Marek, and Renner, 1984; Howe and Shayer, 1981; Meehan, 1984; Shemesh, 1990). Previous researches had found a significant difference in logical thinking abilities between male and female students. Male students performed better in Piagetian formal reasoning tasks as compared to their female counterparts.

Mean Difference in the Acquisition of Logical Thinking Abilities based on Students' Science Achievement at Lower Secondary Level

One-way ANOVA results in Table 5 showed that there is a significant difference in the overall mean of logical thinking abilities according to students' science achievement at lower secondary level ($F(2, 496) = 64.614, p<.0005$). This finding successfully rejected the second null hypothesis which stated that there is no significant difference in the acquisition of logical thinking abilities according to students' science achievement at lower secondary level. On the other hand, one-way ANOVA revealed that there is a significant difference in the mean of conservational reasoning ($F(2, 496) = 35.156, p<.0005$), proportional reasoning ($F(2, 496) =$

TABLE 5

One-way ANOVA results for mean difference in logical thinking abilities based on students' science achievement at lower secondary level (n = 499)

Subscales	Sources of Variation	SS	df	MS	F	p
Conservational reasoning	Between group	70.785	2	35.393	35.156*	< .0005
	Within group	499.339	496	1.007		
	Overall	570.124	498			
Proportional reasoning	Between group	20.605	2	10.302	19.497*	< .0005
	Within group	262.085	496	.528		
	Overall	282.689	498			
Controlling variables	Between group	9.149	2	4.574	13.983*	< .0005
	Within group	162.266	496	.327		
	Overall	171.415	498			
Probabilistic reasoning	Between group	4.260	2	2.130	10.608*	< .0005
	Within group	99.600	496	.201		
	Overall	103.860	498			
Correlational reasoning	Between group	.295	2	.147	.435	.648
	Within group	168.146	496	.339		
	Overall	168.441	498			
Combinatorial reasoning	Between group	10.804	2	5.402	14.380*	< .0005
	Within group	186.318	496	.376		
	Overall	197.122	498			
Overall	Between group	474.691	2	237.345	64.614*	< .0005
	Within group	1821.934	496	3.673		
	Overall	2296.625	498			

* p < .05

19.497, p<.0005), controlling variables (F(2, 496) = 13.983, p<.0005), probabilistic reasoning (F(2, 496) = 10.608, p<.0005), and combinatorial reasoning (F(2, 496) = 14.380, p<.0005) based on students' science achievement at lower secondary level.

Post-Hoc Tukey's HSD multiple comparison results (Table 6 and Fig. 3) showed that students with better achievement in science scored significantly higher than students with medium and low achievement in science for conservational reasoning, proportional reasoning, controlling variables, probabilistic reasoning, combinatorial reasoning, and logical thinking abilities as a whole.

These mean differences might be due to the existence of possible relationships between logical thinking abilities and students' science achievement as pointed out by Lawson (1982b) and Roadrangka (1995). Logical thinking abilities play an important role in the understanding and learning of abstract science

TABLE 6

Post-Hoc Tukey's HSD comparison results for mean difference in logical thinking abilities based on students' science achievement at lower secondary level (n = 499)

Subscales	Science achievement at lower secondary level	n		Low	Medium	High
			M	1.0444	1.2119	1.9048
Conservational reasoning	Low	180	1.0444	-		
	Medium	151	1.2119	-.1675 (p = .285)	-	
	High	168	1.9048	-.8603* (p< .0005)	-.6928* (p< .0005)	-
			M	.3278	.4172	.7917
Proportional reasoning	Low	180	.3278	-		
	Medium	151	.4172	-.0894 (p = .505)	-	
	High	168	.7917	-.4639* (p< .0005)	-.3744* (p< .0005)	-
			M	.2556	.3179	.5655
Controlling variables	Low	180	.2556	-		
	Medium	151	.3179	-.0623 (p = .585)	-	
	High	168	.5655	-.3099* (p< .0005)	-.2476* (p< .0005)	-
			M	.0944	.1126	.2976
Probabilistic reasoning	Low	180	.0944	-		
	Medium	151	.1126	-.0181 (p = .929)	-	
	High	168	.2976	-.2032* (p< .0005)	-.1850* (p = .001)	-

			M	.3000	.3907	.6429
Combinatorial reasoning	Low	180	.3000	-		
	Medium	151	.3907	-.0907 (p = .372)	-	
	High	168	.6429	-.3429* (p< .0005)	-.2521* (p = .001)	-
			M	2.3222	2.7881	4.5595
Overall	Low	180	2.3222	-		
	Medium	151	2.7881	-.4659 (p = .071)	-	
	High	168	4.5595	-2.2373* (p< .0005)	-1.7714* (p< .0005)	-

* p < .05

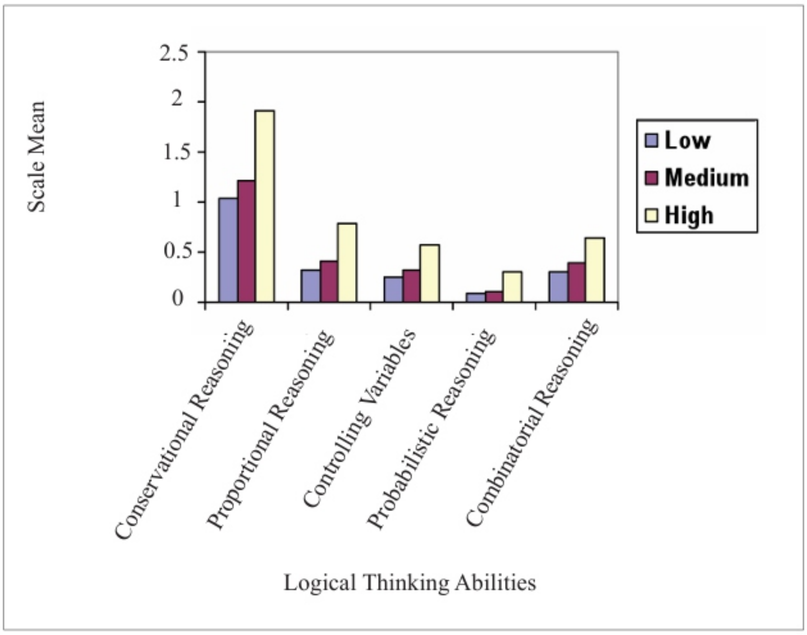

Fig. 3: *Mean difference in logical thinking abilities based on students' science achievement at lower secondary level (n= 499)*

concepts at secondary level and this is translated into better science achievement among students (Lawson, 1982b, 1985; Linn, 1982).

Previous research studies (e.g., Bitner, 1991; Boulanger and Kremer, 1981; Hofstein and Mandler, 1985; Howe and Durr, 1982; Keig and Rubba, 1993; Krajcik and Haney, 1987; Lawson et al., 1975; Lawson, 1982a, b; Marek, 1981; Mitchell and Lawson, 1988; Piburn, 1980; Piburn and Baker, 1989; Roadrangka, 1995; Siti Hawa Munji, 1998; Staver and Halsted, 1985) suggested that formal reasoning abilities are closely related to science achievement. For instance, Lawson (1982b) showed that students' score in 'Lawson Classroom Test of Formal Reasoning' (Lawson, 1978) was correlated with their achievement in school subjects i.e., social studies, science, and mathematics. This finding provides concrete evidence that formal reasoning abilities can also be related to students' general performance, not only to science and mathematics.

On the other hand, Roadrangka (1995) found that there is a relationship between formal operational reasoning abilities and students' achievement in biology, physics, and chemistry. Students at formal operational stage scored significantly higher in biology, physics, and chemistry tests compared to those at concrete operational stage. Students at formal operational stage were also found to obtain significantly higher score in physics and chemistry tests than students at transitional operational stage. Concrete thinkers are unable to develop the understanding of abstract concepts. Conversely, formal thinkers are able to develop the understanding of concrete and abstract concepts (Inhelder and Piaget, 1958). Hence, students' success in science will be guaranteed by using different modes of formal operational reasoning (Lawson, 1982b, 1985; Linn, 1982; Tsaparlis, 2005; Tai et al., 2005; Lewis and Lewis, 2007). For instance, Lewis and Lewis (2007) emphasized the need to include a focus on the development of formal thought as well as a content review in the efforts to help at-risk students in general chemistry.

IMPLICATIONS OF THE STUDY

In the effort to develop students' logical thinking abilities, some changes in the evaluation system and science teaching and learning strategies need to be seen more intentionally. In relation to this, different subjects such as planning and developing instructional programs, classroom activities, laboratory activities, teaching materials, measurement-assessment methods, and pre-service teacher education strategies need to be considered for the purpose of developing students' cognitive thinking abilities (Schneider and Renner, 1980; Moshman and Thompson, 1981; Akdeniz, 1993; Çepni and Özsevgeç, 2002; Özsevgeç, 2002).

The importance of logical thinking abilities in our education system as emphasized by Renner and Philips (1980, p.193): "The purpose which runs through and strengthens all other educational purposes – the common thread of education is the development of the ability to think" needs to be fully understood by all the relevant parties (e.g. Curriculum Development Centre, schools, science teachers) who are involved directly and indirectly in the planning and implementation of science curriculum in this country. As pointed out by Renner and Philips (1980), students should be given more opportunities to develop their thinking abilities for intellectual development via various approaches. In relation to this, Yaman (2005) has shown that problem-based learning (PBL) approach was effective in the development of logical thinking skills. On the other hand, the creative and critical thinking based laboratory method was also found effective in developing creative and logical thinking abilities (Koray and KÖKSAL, 2009).

Hence, logical thinking abilities should be given new emphasis in the teaching and learning of science in the effort to improve students' science achievement at all levels of schooling.

Lawson (1985) stressed that the schooling system is not meant for the teaching of facts and concepts which are specific to a particular knowledge domain, but to assist students in acquiring thinking skills.

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Students' Perception of the Teaching of Historical Thinking Skills

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A B S T R A C T

History is a compulsory subject for all Malaysian secondary school students. History teaching and learning processes focus on historical thinking skills such as chronology, exploring evidence, making interpretations, imagination, and rationalizing. Competency in historical thinking skills enables students to think critically and creatively, to understand historical criteria, to perceive historical events emphatically, to explore complex and abstract ideas, and to appreciate ways historians construct past events using evidence to establish historical significance. A study on students' perceptions of the teaching of historical thinking skills in the subject was conducted in two secondary schools in Miri, Sarawak. The participants were 80 Form Four Science and Arts stream students. The findings showed students' perception of the teaching of historical thinking skills range from moderate to moderately high level. The result also showed no significant difference in perception between male and female students on all four historical thinking skills (chronology, exploring evidence, interpretation, and imagination). However, on the skill of rationalizing, male students showed a more positive perception (mean=3.85) compared to female students (mean=3.63). In addition, the t-test showed no significant difference in perception between Science and Arts stream students on four aspects of historical thinking skills (chronology, interpretations, imagination, and rationalizing). On the skill of exploring evidence, Arts students showed a more positive perception (mean=4.16) compared to Science students (mean=3.64). The implication of this study is that history teachers need to equip themselves with historical thinking skills so that the process of teaching and learning can be more effective which in turn could help enhance students' acquisition of historical thinking skills.

Keywords: History education, history curriculum, historical thinking skills, secondary school, Malaysia

INTRODUCTION

Many decades ago, Dewey (1916) in his book Democracy and Education observed that, "All which the school can or need do for pupils, as far as their minds are concerned is to develop their ability to think" (cited in Schleifer, 1997, p. 78). Many educators support Dewey's rallying cry that education should be about developing children's thinking, not by telling them what to think, rather by helping them to find their own paths to meaning. If thinking is about how children make sense of things, then developing their thinking skills will help them gain more out of learning and out of life. Teaching children to be good thinkers is both a rational and a moral effort and can be seen as the fulfilment of the potential of individuals through particular processes of education. These processes require more than mere isolated sets of thinking skills. They are inevitably also a matter of developing attitudes and dispositions.

In studying history, the main objective is the acquisition of knowledge and understanding. It is with understanding that provides the frame of reference within which the items of information or historical facts find their place and meaning. History differs from most other subject matter in that it's central concern is with the action of people and the significance and consequences of those actions. Historical events cannot be understood without reference to the motives and beliefs of the participants, although there can never be absolute certainty why they acted as they did. Despite the concern for evidence and rigour, historians have to make selections from the mass of evidence available and offer an interpretation of why and how events occurred as they did. This is because the wider the base of information, the greater the potential for developing understanding through the perceptions of significant connections and relationships (Fisher, 2008).

HISTORY IN THE SCHOOL CURRICULUM

History has been an integral component of the school curriculum. School history in particular, frequently is seen as a vehicle in which students supposedly learn the civic lessons that will influence them to become dependable and useful citizens. Thus history education plays its role to pass on desirable social attitudes, values, and behaviours (Cuban, 2001). In the Malaysian context, history has been recognized as an important subject in the effort to produce loyal and patriotic Malaysian citizens. To help nurture the spirit of citizenship, history learning is made compulsory to all students at both lower and upper secondary levels. Recently, there has been talk that history learning should begin at Year 1 in the primary school. The new status given to history is a significant change from the former curriculum whereby history was an optional subject at upper secondary level. Students could opt not to learn history while those in the science stream had been discouraged from learning history as a school subject (Abdul Rahim, 1999; Abdul Ghani 2008).

Despite the importance of history, its intended purpose and its alleged civic significance in school curriculum arguments remain about the quality of history education. As early as the nineteenth century, psychologist G. Stanley Hall (cited in Wineburg, 2004) claimed that history was the most poorly taught in school, and current researchers have claimed that its popularity has not grown. Surveys reveal that adults look back on history courses as "boring" and students' perceptions remain that history is boring and is poorly taught (Seixas, 2004; Wineburg, 2004). Unsurprisingly, a number of parties have levelled criticisms concerning the teaching and learning of history and poor achievement in the subject, and expressed dissatisfaction with the way teachers are teaching the subject. Not only students have become victims, but history as a subject continued to be perceived as "boring" and "side-lined" due to ineffective teaching strategies (Abdul Rahim, 1999; Aini Hassan, 1999).

TEACHING HISTORICAL THINKING SKILLS

Historical thinking skill (HTS) is generally defined as a process of using historical information, including deciphering context, perspective, point of view, and perceived facts to understand the past. Thinking in history, or the use of phrases such "thinking history" also may refer to a process of using critical thinking skills or higher level of thinking skills in the study of history. Other researchers in the field have defined the term "historical thinking" as simply "thinking like a historian". This definition implies that a person's effort and ability to place historical information or a historical document, including interpretations, meanings, and context, into the social setting in which it was created. Profesional historians use the process of defining value, objectivity, bias, sources, and content when interpreting and evaluating historical information or primary source documents. Helping secondary students to accomplish this task in history education is one of the challenges faced by many history teachers (Cuban, 2001; Seixas, 2004; Wineburg, 2004).

HTS is important to history education for several reasons. History provides opportunities to teach process skills, such as critical thinking, data analysis, making or identifying generalization, discovering biases, and recognizing perspectives. Recent studies have included the concept of historical empathy, or understanding the deeper context of historical events. Developing these skills through history learning would help students to develop process skills that enable them to engage in higher order thinking skills. The emphasis on historical thinking is seen as the key to helping students better understand the historical content by understanding the historical context. Providing opportunities for students to develop these higher level thinking skills prepares them to exercise a greater understanding of the past, but also increase awareness of their own perceptions and cultures and a greater understanding of others (Wineburg, 2004; Yeager and Foster, 2001).

The Malaysian Secondary School Integrated Curriculum, better known as KBSM, emphasizes teaching and learning processes that focus on the development of critical and creative thinking skills (CCTS) across all subjects. The thinking skills (TS) that students need to master are categorized into two components: critical thinking skill and creative thinking skills (KPM, 2004). Critical thinking is defined as the ability to evaluate, to judge, and to draw conclusion of an idea or concept. Creative thinking is the ability to generate and create original ideas. The CCTS are arranged in hierarchical order from basic skills to more complex skills. The CCTS model adopted by the Ministry of Education (KPM), as shown in Fig. 1, serves as a guide for teachers in developing CCTS in the process of teaching and learning.

In the KBSM history curriculum, CCTS is realized through the concept of Historical Thinking Skills (HTS) which is defined as a

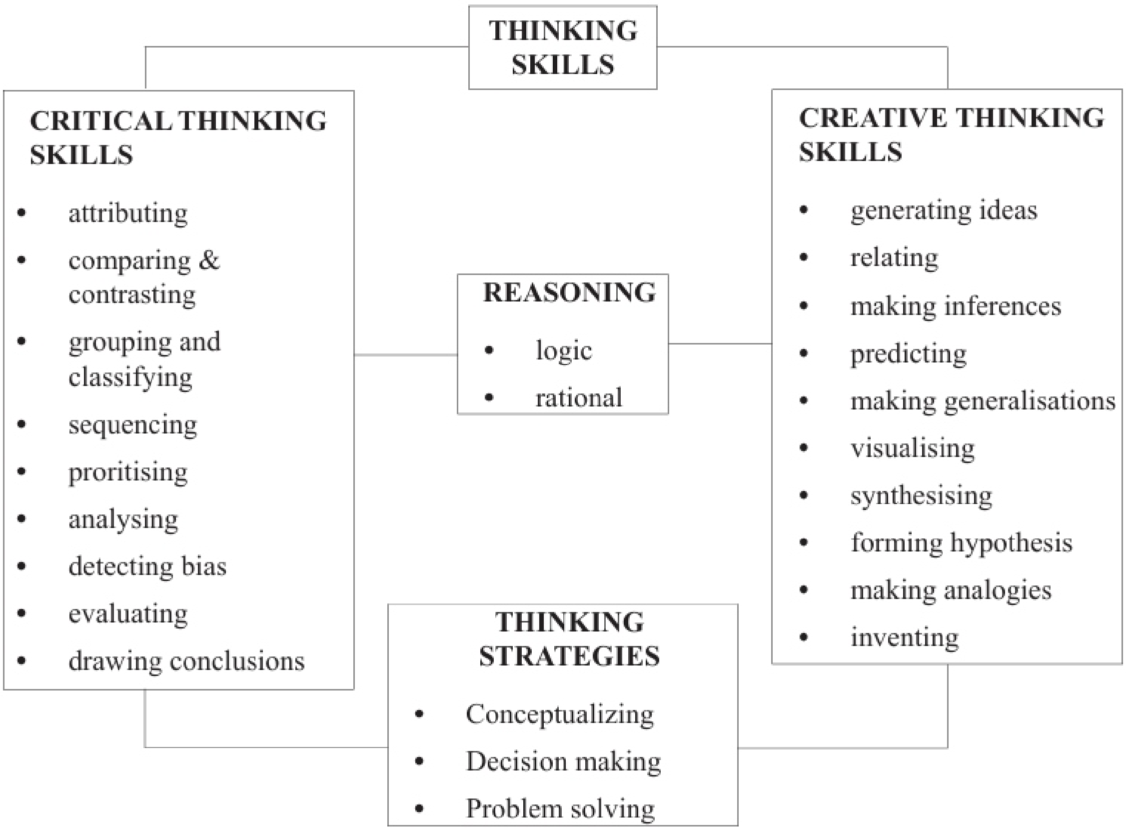

Fig. 1: *The CCTS Model (KPM, 2004, p.9)*

cognitive process that enables students to explore complex and abstract ideas in learning history. The HTS that have been identified are as follows:

I.

Chronology: this skill comes under the critical thinking skill of sequencing. Chronological Skills contain two important elements: timelines and time convention. Timelines contain a series of events which happened according to chronology whereas time convention involves dates and events.

ii. Chronology: this skill comes under the critical thinking skill of sequencing. Chronological Skills contain two important elements: timelines and time convention. Timelines contain a series of events which happened according to chronology whereas time convention involves dates and events. Exploring Evidence: this is the critical thinking skill which emphasizes the skill of identifying primary and secondary sources and then comparing them.

iii. Interpretation: is the skill of analysing a historical event by analysing and explaining it through teaching and learning activities. Competence in this skill enables students to become aware of the fact that historians and researchers of history do analysis and that they will differentiate between facts in using the perspectives of historians.

iv. Imagination: is linked to perceptions of the mind or on thoughts or visualising an idea, concept, situation or event. Through imagination students develop empathy in the situations of an event.

v. Rationalizing: is the highest skill as it requires the skill of evaluating an event. Rationalizing requires students to go through the cognitive process of thinking and making sound evaluations as they resolve the issues involved in historical events.

In the History Learning and Teaching Module (KPM, 2000), the objectives of applying HTS are to enable students to: i) think critically and creatively; ii) understand the features of history; iii) develop empathy for historical events; iv) explore complex and abstract ideas with the teacher's guidance; and v) understand how historians re-construct past events using evidence to determine the significance of certain events. These objectives would be achieved through organized teaching and learning activities in the classroom. Consequently, teachers need to rectify their teaching styles and learning activities and adapt their instructional methods to the development of HTS using investigative methods such as questioning, simulation, evaluating, assessing and arguing. Students participate actively in the learning process through series of activities including role-plays, historical simulations, and classroom discussion. Using primary source document, written, visual and photographic evidence the teacher sought to develop and build students' abilities in HTS.

STUDENTS' PERCEPTION OF THE TEACHING OF HTS

This study was designed to examine what occurred in the classroom on the teaching of HTS and higher order thinking skills. The main aim was to look into students' perception on the instructional methods employed by their teacher to help inculcate HTS. Specifically the objectives of the study were:

1. To identify the students' level of perception of the teaching of HTS.

TABLE 1

Perception level

Mean score	Perception level
1.00 - 2.33	Low level
2.34 - 3.66	Moderate
3.67 - 5.00	High

2. To determine differences in student's perception towards the teaching of HTS between male and female students.
3. To determine differences in students' perception towards the teaching of HTS of Science and Arts students.

METHODOLOGY

A survey method using questionnaires was chosen for the study. The respondents comprised eighty (N=80) Form 4 students from SMK Baru Miri (n=40) and SMK Merbau (n=40) in Miri Division, Sarawak. The choice of location was of convenience since a writer of this article was

TABLE 2

Mean values of students' level of perception on the teaching of HTS

HTS	Item	Mean	Std. dev.
Chronology	Q1.Teacher relates past, present and future events.	3.83	0.973
	Q2.Teacher sequences times and events.	3.75	0.893
	Q3.Teacher identifies changes and progress over time.	3.86	0.910
	Q11.Teacher arranges lessons systematically.	4.05	0.966
	Q27.Teacher shows progress using time lines and sequences of events.	3.56	0.978
Exploring evidence	Q16.Teacher guides students to search for information.	4.07	1.052
	Q18.Teacher participates in activities.	4.12	4.12
	Q19.Teacher encourages the collection of information from primary and secondary sources.	3.52	0.856
	Q20.Teacher uses a variety of resources.	3.89	0.993
	Q22.Teacher uses diverse teaching methods.	3.80	3.80
	Q24.Teacher uses many resources to teach HTS.	4.01	0.947
Interpretation	Q4.Teacher compares resources for factual evidences.	3.94	1.035
	Q5.Teacher generates ideas.	3.64	0.997
	Q7.Teacher analyzes historical events.	3.65	1.007
	Q8.Teacher differentiates facts and interpretations.	3.69	1.038
	Q12.Teacher uses mind maps.	4.15	0.969
	Q21.Teacher uses different learning resources.	3.81	0.901
Rationalizing	Q6. Teacher draws conclusion using logics.	3.56	0.979
	Q10.Teacher draws conclusion based on historical evidence.	4.03	0.683
	Q13.Teacher gives rationales for historical events.	3.90	0.963
	Q15.Teacher resolves problems on certain issues raised by historical events.	3.47	1.030
	Q28.Teacher creates situations for discussion.	3.26	1.003
	Q29.Teacher raises questions on critical thinking.	3.70	0.919
	Q30.Teacher tests thinking skills on history.	3.91	1.008

a teacher in one of the schools. The respondents consisting of twenty male and twenty female students from the Science and Arts stream were randomly selected from the two secondary schools. In both schools the history test results in the 2007 Penilaian Menengah Rendah (Lower Secondary Assessment) for SMK Baru Miri showed 62.74% students scored Grades A, B, and C while in SMK Merbau 56.85% scored Grades A, B, and C. Female students performed better than male in both schools with 71 female students scored Grades A and B in SMK Baru Miri and 95 female students scored Grades A and B in SMK Merbau. Generally, students with good performance in the PMR are placed in the Science stream. Since history is a core subject, both Science and Arts have to learn history.

Data was collected using a 30-item, 5-point Likert scale (Strongly Disagree – Strongly Agree) questionnaire. The questionnaire comprised two parts: part A is about the demography of respondents. Part B comprised of statements on perception of the teaching of HTS: Chronology (5 items), Exploring Evidence (6 items), Interpretation (6 items), Imagination (6 items), and Rationalizing (7 items). Prior to the data collection, a pilot study of the instrument was conducted with a class of students in a different school in Miri. The internal consistency of the instrument was found to be at r=0.96 (Cronbach Alpha). The data collected in the study was analyzed using descriptive statistics (frequencies, means, and standard deviations) and inferential statistics (t-tests). The significance level or alpha was set at p= 0.05. The level of perception of the students on the teaching of HTS was gauged using the following scale.

RESULTS

Students' Level of Perception towards the Teaching of HTS

Data was analyzed by examining each of the items in the five HTS identified in the history curriculum. The means and standard deviations students' responses for each item on all five HTS namely Chronology, Exploring Evidence, Interpretation, Imagination, and Rationalizing are shown in Table 2. Out of 30 items in the questionnaire, Item 12, "teacher uses mind maps" has the highest mean (M=4.15) with SD=.969. The second highest is Item 18, "teacher participates in activities" (M=4.12 with SD=.972), followed by Item 16, "teacher guides students to search for information" (M=4.07 with value of SD=1.052). The lowest mean is Item

TABLE 3

Difference in perception towards the teaching of HTS based on gender

Skills	Gender	N	Mean	Standard deviation	df	t value	P
Chronology	Male	40	3.79	0.63	78	-0.264	0.79
	Female	40	3.83	0.55			
Exploring	Male	40	3.87	0.67	78	-0.414	0.68
Evidence	Female	40	3.93	0.57			
Interpretation	Male	40	3.83	0.58	78	0.300	0.76
	Female	40	3.79	0.58			
Imagination	Male	40	3.66	0.77	78	0.158	0.87
	Female	40	3.63	0.64			
Rationalizing	Male	40	3.85	0.37	78	2.465	0.01*
	Female	40	3.63	0.40			

Significance level p=0.05

TABLE 4

Difference in perception towards the teaching of HTS based on stream

Skills	Stream	N	Mean	Standard deviation	df	t-value	P
Chronology	Science	40	3.86	0.53	78	0.719	0.47
	Arts	40	3.76	0.63	78		
Exploring	Science	40	3.64	0.64	78	-4.021	0.00*
Evidence	Arts	40	4.16	0.49	78		
Interpretation	Science	40	3.72	0.54	78	-1.465	0.15
	Arts	40	3.91	0.60	78		
Imagination	Science	40	3.58	0.58	78	-0.792	0.43
	Arts	40	3.71	0.80	78		
Rationalizing	Science	40	3.68	0.38	78	-1.340	0.18
	Arts	40	3.80	0.41			

Significance level = 0.05

28, "teacher creates situation for discussions" (M=3.26 with SD=1.003). In general students' perception on the teaching of HTS ranged from moderate to moderately high in all the five HTS.

Students' Perception towards the Teaching of HTS Based on Gender

Table 3 shows the means of the students' perception toward the teaching of HTS based on gender. The results showed that there was no significant difference on the skills of chronology, exploring evidence, interpretation, and imagination based on gender. Both male and female students' seemed to have similar perceptions of teachers' teaching of HTS. However for the skill of rationalizing, the t-test showed a significant difference in perception towards the teaching of HTS based on gender. Apparently male students have a higher perception (M=3.85) towards rationalizing as compared to female students (M=3.63).

Students' Perception on the Teaching of HTS Based on Stream

Table 4 shows the results of t-test in perception of the teaching of HTS based on the stream of study The finding showed that there was no significant difference on perception of Science and Arts students on four HTS namely chronology, interpretation, imagination, and rationalizing in history learning. However, a close scrutiny revealed that Science seemed more critical in their perception of history teachers with a mean score lower compared to Arts students. For HTS on exploring evidence, the Arts students gave high perception (M=4.16) compared to the Science students (M=3.64).

DISCUSSION

The findings of this study indicate that students in both schools perceived the efforts made by their history teachers in teaching historical thinking skills as moderately high. Data analysis using t-test indicates there was no significant difference in the students' perception of the teaching historical thinking skills between male and female students irrespective of Science or Arts classes. Based on the analysis of the students' perception, it can be inferred that the history teachers in both schools did not fully exhibit strong traits of historical thinking skills in their teaching and learning activities, indicating that they possessed limited ability to "think like historians". If teachers entering history classes with limited ability in historical thinking skills, then it can be expected that they will not be able to develop the myriad of skills in their students. The finding in this study supported the reports by Zahara and Nik Azleena (2007) on the readiness of teachers to teach historical thinking skills. Their study which involved 114 history teachers in the Dungun Terengganu showed that teacher's readiness with regard to the teaching of historical thinking skills were moderate as a whole. The findings also indicated that there was a significant difference between teachers who were trained to teach history and those who were not (Zahara and Nik Azleena, 2007).

Teachers bring with them to the classrooms their vision of history and how history should be taught. Often this history represents the history they learned in their schooling or university education. Just as students' historical thinking is significant, one can argue that teachers must be prepared to teach historical thinking skills. Whether acting as a facilitator or teaching students step by step in scaffolding methods, they need to know how to teach historical thinking. They must be aware of their own ability to use the appropriate resources, approaches, activities, and to think like historians in order to guide students to success. If teachers enter classroom with a limited vision of history, or without preparation in teaching or helping students to analyze data sources and to think critically about the data, then they cannot be expected to teach higher order thinking or exhibit strong traits of thinking like historians. Administrators, teacher education programs and teachers themselves should be concerned with the development of teachers and that teachers are adequately prepared to teach students to think historically.

In his day, Hall (cited in Wineburg, 2004) promoted two ideas to rectify his concerns about poor teaching of history. First, history teachers should be subject specialists who knew and understood their subject matter, and second, that schools should increase time devoted to historical studies. Hall further argued that teachers should adapt their instructional methods to the developmental level of their students, including efforts to learn history using an investigative method, a notion that appears similar to the current concept of historical thinking. The findings of this study indicate that history teachers have not diversified their instructional methods to the developmental level and student ability. Apparently teachers used similar strategies and activities to both Science and Arts classes. Wineburg (2001) emphasized that teachers need to use history education as a vehicle to higher level thinking, arguing that history provides a significant opportunity to teach these higher level of critical thinking skills. In this sense, history curriculum and history teaching serve as a means in developing critical and creative thinking skills. Historical thinking skills involve certain distinct problems that cannot be collapsed into mere generic critical thinking (Seixas and Peck, 2004). In this study, students perceived the skill of imagination being the least emphasized by history teachers. Imagination is important because the history of an event, place, background, time frame, names, and time period will be difficult to visualize if merely words are used. Husband (1996) asserts that the skill of using imagination enables students to enter the minds, and to empathize with the feelings, of those involved in a particular historical event. It is an ability to see and understand the world from a perspective not our own. Imagining must be based on historical evidence if it is to have any meaning. Exercises that ask students to imagine being a medieval knight or a Malay Chieftain of Melaka make no sense unless they have rich information about life during those times.

CONCLUSION

One must be careful not to extrapolate general conclusions based on a study which focused on a small number of participants as in the present study. This study has examined how students perceived the teaching of historical thinking skills by their history teachers. Nonetheless the findings of this study may provide indications what concur in the classroom regarding the teaching of historical thinking skills. Accepting the notion that students can learn to think like historians relies on the belief that teachers have the ability to think like historians and are able to guide students through the process. Teachers' ability and preparation determine what is happening in the classroom. Effective teaching of history depends largely on the efforts and approaches of the teacher. Inevitably, history teachers have to be prepared with knowledge and effective skills of teaching history. Teachers also have to listen to the views and opinions of students about their teaching methodologies that can help make history lessons more meaningful and appealing.

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Impact of Multimedia Instructional Materials on Creative Thinking

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A B S T R A C T

This study aimed to investigate the impact of utilising multimedia instructional materials (MIM) on engineering students' creative thinking in Malaysia. Fifteen MIM were developed based on the principles of Cognitive Theories of Multimedia Design (Mayer, 2001) and Cognitive Load Theory (Sweller et al., 1998). The MIM were used by 27 mechanical engineering students in lab sessions over a period of 5 weeks. Torrance Tests of Creative Thinking (TTCT) verbal forms A and B were administered to the students as pretest and posttest respectively to measure students' creative thinking in terms of fluency, flexibility, originality, and overall creativity capabilities. Two semi-structured focus group interviews were also conducted with five volunteer students in each group. Data were analysed using a paired sample t-test comparing pre and posttests results and also between genders. The t-test analysis shows that there was a significant increase in the students' creative thinking in the posttest for all the creative thinking elements stated. Students' responses during the interview supported the statistical findings.

Keywords: Cognitive load, creative thinking, multimedia learning

INTRODUCTION

Creativity requires knowledge. Creative acts do not simply appear in a flash although it is undeniably true that some individuals are naturally gifted with such a talent (Guildford, 1950). For all other individuals born without the natural gift of creative potential, creativity is a skill that can be learnt (Amabile, 1998). It requires among other things, knowledge, and it entails the cognitive interplay between new and existing knowledge (de Bono, 1990; Sweller, 2009). De Bono (1990) states that the cognitive process of creativity involves the ability to use and communicate ideas, and how new and old ideas are manipulated to create one's own novel ideas. This cognitive manipulation of ideas and knowledge is part of the complex phenomenon of the human cognitive system which is often explored as an information processing system (Sweller, 2009). A system which includes working memory, long term memory and schemas, and how these three components are able to process, integrate, and transform information into knowledge which might lead to novel ideas.

The advancement of knowledge and changes in how information can be represented in today's technological era also affect how information can be cognitively manipulated. The growth of computer technology has made it possible to transform commonly static and paper-based representations into pictorial and dynamic representations (Mayer, 2001). It was generally based on this development that Cognitive Load Theory (CLT) (Sweller et al., 1998) and Cognitive Theory on Multimedia Design

(CTMD) (Mayer, 2001) were proposed in order to address how multimedia instructional materials can be designed effectively to ensure appropriate load on learners' cognitive systems, and therefore, facilitate meaningful learning.

Studies of multimedia learning are not entirely new in educational research. The emphasis has however been mostly on retention, transfer and problem-solving performance (Mayer and Anderson, 1992; Mayer et al., 2007; Paas et al., 2007; Seufert and Brünken, 2006). The literature that relates the significance of multimedia learning to the enhancement of creative thinking is scant. Sweller (2009) has recently described the human cognitive architecture based on evolutionary biology and instructional processes (in relation to CLT) that could facilitate creativity. There is however no description of the cognitive architecture and its association with multimedia learning. This study, therefore, was an attempt to investigate whether the use of multimedia instructional materials (MIM), which were designed based on four principles of CTMD, could enhance engineering students' creative thinking.

APPROPRIATE DESIGN OF MULTIMEDIA INSTRUCTIONAL MATERIALS FOR CREATIVE THINKING

This study has its basis in cognitive load, multimedia learning, and creativity theories. Fig. 1 depicts the framework which was used for the design of the MIM. The framework was adapted from the principles of CTMD and CLT (Mayer, 2001; Sweller et al., 1998). The framework considered the load on students' cognitive system in order to ensure that information can be processed appropriately to assist students in the enhancement of their creative thinking.

Cognitive Load and Multimedia Instructional Design

Cognitive Load Theory (CLT) focuses its argument on the assumption that effective and meaningful learning occurs when the interaction between the architecture of the human cognitive system and the learning environment is understood and accommodated. There is a need to understand firstly, what is

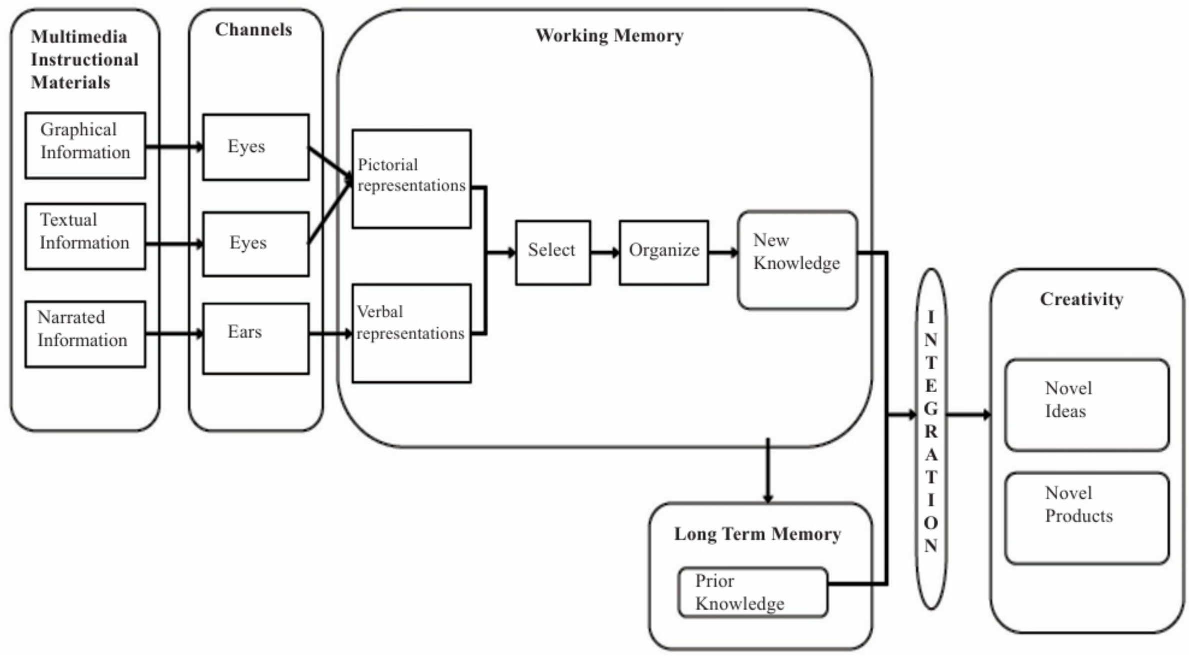

Fig. 1: *Framework for the design of multimedia instructional materials to promote creative thinking*

involved in building the complex system of human cognition and in what ways the elements function and secondly, how the instructional materials should be designed and developed in order to accommodate this complexity (Cook et al., 2009; Paas and Kester, 2006). CLT posits that the human cognitive system consists of a working memory which is limited in its capacity and duration and the effectively unlimited but schematic long-term memory. Schema is the form in which knowledge in long-term memory is stored, and schema is the categorisation of information according to its manner of use (Sweller et al., 1998). The design of the learning materials should accommodate this structure to ensure that information processed in the working memory can be constructed and transferred into and retrieved from long-term memory without cognitively overloading the working memory (Cook et al., 2009; Paas et al., 2003; Sweller et al., 1998). Appropriate load in the working memory can ensure that students are able to process the interacting elements of information and even process novel ideas in the working memory. Cognitive load in the working memory is therefore an essential part of the human cognitive system that should be considered when designing instructional materials.

According to CLT, there are two types of cognitive load: intrinsic and extrinsic cognitive loads. Intrinsic cognitive load refers to the natural load imposed by the complexity and interacting elements of the information which has to be simultaneously processed in working memory. These interacting elements are the different types of information that students have to assimilate from the instructional materials for comprehension, and that the instructors have no control over this load (Ayres and Paas, 2007; Cook et al., 2009; Sweller et al., 1998). Extrinsic cognitive load can be further categorised into two: a) extraneous and b) germane cognitive loads. Extraneous cognitive load is imposed by design of the instructional materials that can hinder students' understanding whereas germane cognitive load is extrinsic cognitive load imposed by instructional materials that can actually foster the learning process (Paas et al., 2007; Sweller et al., 1998). Fig. 1 shows that both textual and graphical information enter into the cognitive system through the eyes, and the narrated information through the ears.

Hence, instructional designers have to ensure that each type of information presented in the instructional materials accommodates the other type. Too much textual information to support a graphical image or narrated information which is not synchronous with the graphics may inflict extraneous cognitive load, and therefore, hinder students' understanding.

Moreover, all the cognitive loads are considered additive in CLT, and together they build the overall construct of cognitive load (Cook et al., 2009; Paas et al., 2007). In order for learning to be maximized, the total load should not exceed working memory capacity. CLT also postulates that learning can be affected by students' individual characteristics. Thus, the design of instructional materials, use of multimedia, complexity of task and even students' characteristics need to be considered to ensure increase in germane cognitive load without increasing extraneous load. When this occurs, schemas can be constructed and transferred into long-term memory, and the interaction between the newly built schemas and previously constructed schemas in the longterm memory may assist in the production or construction of novel ideas.

Principles of Multimedia Instructional Design

Studies of multimedia learning have been conducted for several decades, and the focus has been mostly on the design of the multimedia instructional materials and its impact on students' learning and understanding (Mayer, 2001: 2002). The Cognitive Theory of Multimedia Design which was developed based on numerous studies (Harp and Mayer, 1998; Mayer and Anderson, 1992; Mayer and Chandler, 2001; Moreno and Mayer, 1999; Moreno and Mayer, 2000) lists eight principles of how MIM should be designed. The theory suggests ways to ensure appropriate load on students' cognitive system so that effective learning can be facilitated (Mayer, 2001: 2002). This paper describes four of the principles (Mayer, 2001: 2002) in relation to the design of the MIM used in the study.

- ***Multimedia principle:*** Meaningful learning can be attained when the MIM include both relevant pictures and words rather than words alone. This is based on the assumption that pictorial information enters into the cognitive system through the eyes while verbal information enters into the cognitive system through the ears. Therefore, both channels of receiving information should be used effectively so that one channel is not overloaded when only one kind of representation of information is presented (Mayer, 2001: 2002).

• **Contiguity principle:** Meaningful learning can be attained when the MIM presents the animated and narrated information simultaneously rather than sequentially. This is based on the assumption that when both the visual and auditory channels are used to enter information into the cognitive system, the chances are high that matching words and pictures may be in the working memory at the same time. Therefore, learners should be able to construct mental connections between them. Studies of this principle indicated that concurrent presentation between animation and narration increases the temporal processing of the cognitive system, reduces overall cognitive load and positively affect students' retention and transfer (Mayer and Anderson, 1992; Moreno and Mayer, 1999).

• **Coherence principle:** Meaningful learning can be attained when the MIM excludes irrelevant and extraneous words, sounds, and animations. This is based on the assumption that extraneous information may increase the extraneous cognitive load, and therefore, overload working memory. Studies by Mayer and colleagues on the insertion of interesting but irrelevant words and pictures (Harp and Mayer, 1998), or sounds and music (Moreno and Mayer, 2000) showed that understanding was negatively affected.

• **Interactivity principle:** Meaningful learning can be attained when the MIM provides students with the ability to control the presentation rate. This is based on the assumption that user interactivity can reduce the chances of cognitive overload by enabling students to be involved in the cognitive process at their own pace. Studies of this principle revealed that as an instructional technique, pacing could assist students to reduce extraneous cognitive load in their cognitive system because pacing allows students to adapt the multimedia presentation to their own cognitive abilities and needs (Hasler et al., 2007; Mayer and Chandler, 2001; Mayer et al., 2003).

Cognitive Process Leading to Creative Thinking

Due to the complexity and mystery of its nature, different researchers and theorists have come up with different interpretations of creativity. Yet, most of them agree that one of the important criteria in being a creative individual is knowledge, and how a person is able to use new information and connect prior knowledge to produce something original, novel and practical (Amabile, 1998). Therefore, based on the framework in Fig. 1, in order to relate CLT and CTMD, we are assuming that the design and development of the MIM should consider the students' cognitive system. Since MIM can include graphical, textual and narrated information, the manipulation of these representations of information should ensure that the MIM creates appropriate load in the cognitive system so that new information can be effectively constructed into the learners' new schemas. Newly constructed schemas can be successfully transferred into long-term memory, or they can be manipulated or integrated in working memory with the existing schemas from long-term memory in order to produce novel ideas. Essentially, to develop MIM that would be helpful to enhance students' creativity, students' cognitive load (as outlined in CLT) needs to be considered in the instructional design of the MIM (as outlined in CTMD).

METHODOLOGY

The objective of this study was to explore the impact of multimedia instructional materials on engineering students' creative thinking. On the other hand, learner characteristics such as attitudes, learning styles, academic achievement, and gender are also essential factors in both CLT and CTMD that are worth exploring, but for this study the distinction in the creative thinking results were compared against learner characteristics only in terms of one learner characteristics, gender.

Participants

The sample consisted of 27 third year mechanical engineering undergraduates (20 males and 7 females) from an engineering-based university located in Kuantan, Malaysia. The age range of the students was from 21 to 26 ($M = 22.22$), and they were all enrolled in a Mechanism Design subject, one of the compulsory subjects required for graduation. Third year students were chosen since many creativity theorists postulated that to illustrate creative abilities, knowledge is a component that plays an important part in the process (Amabile, 1998; Sweller, 2009). When the pilot study was conducted, the participants had completed 17 credit hours of the university compulsory courses and 45 – 50 credit hours of program courses. They had also passed the prerequisite course, Dynamics.

Materials

Fifteen multimedia instructional materials (MIM) were designed and developed based on the content of chapter one of the textbook entitled Machines and Mechanism: Applied Kinematic Analysis by David H. Myszka (2005). A computer engineering student from a different university was recruited to design and develop the MIM. The content of the MIM covered concepts from almost 80% of the chapter, and the topics chosen were based on the topics that were outlined in the course syllabus. There were f ive main topics with individual MIM and two of them contained multiple sub-topics with several MIMs. The length of each MIM ranged from 13 to 86 seconds ($M = 33.69$).

The design and development of the MIM were based on the four principles of Mayer's (2001) Cognitive Theories for Multimedia Design (CTMD) as described in the earlier section. Three different software tools were used in the development of the MIM. These included software to 1) build the models and animation, 2) edit the audio and the video clips, put the text and sound together, and finally 3) combine all MIM and present them according to chapters, topics and sub-topics in a multimedia program.

Fig. 2 shows the screenshot of one multimedia element. The list of the topics for the chapter appears on the right, and by doubleclicking on the topic, the multimedia element could be played. Since studies have shown that interactivity elements can reduce cognitive load (Hasler et al., 2007; Mayer and Chandler, 2001; Mayer et al., 2003), the interactivity principle of the CTMD was applied in the design of this MIM. The students were able to control the multimedia by right-clicking anywhere on window, which causes the menu option to appear. Through this drop-down menu, students were able to pause, play and stop, control the speed and volume and even zoom the multimedia to full screen.

To adhere to the coherence principle, there were also no extraneous images, words or sounds added into the MIM. Even though the list of topics appears on the right, students were able to zoom the multimedia to full screen to solely watch the MIM. The textual information was limited to (i) the identification of the parts of the mechanism, (ii) representation of the mechanism in graphics, and (iii) calculation steps to show the use of equations whenever they were necessary. Both the multimedia principle and the contiguity principle were also applied where animation and narration were presented

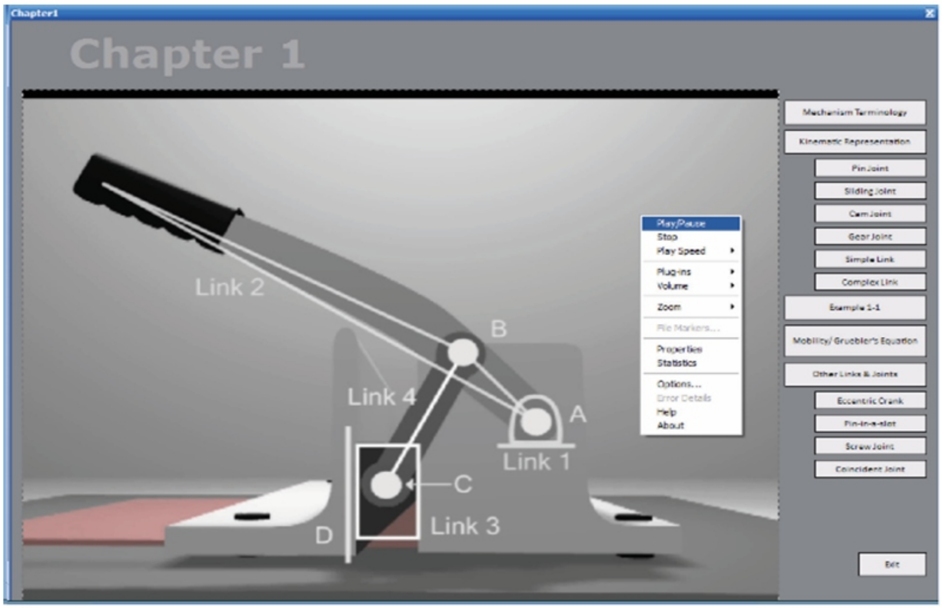

Fig. 2: *Screenshot of multimedia instructional materials*

concurrently. For instance, while the movement of the mechanism was shown, the explanation of the mechanism was narrated, and sometimes the link would either be highlighted or the graphical representations of the mechanism would be shown.

After the completion of the development of each MIM, the individual multimedia file was sent to the lecturer teaching the course as the content expert to check on the accuracy of the textual, narrated, and graphical representations of information as well as the dynamic representation of the information.

Instruments

Torrance Tests of Creative Thinking (TTCT)

The Torrance Tests of Creative Thinking (TTCT) were developed by E. Paul Torrance and his associates in 1966, and are among the most quoted and referred creative thinking tests. The tests have been renormed several times 102 (Cramond and Kim, 2002) and the latest version of the tests (Torrance, 1998a, b) was used in this study. The creative thinking tests consist of (I) two verbal forms which require respondents to provide answers in words and (ii) two figural forms which require respondents to draw the answers. Both verbal forms (A and B) of the TTCT were used in this study. TTCT verbal form A was used as the pretest, and TTCT verbal form B was used for the posttest. The purpose of using TTCT was to measure whether there was any significant difference in the students' creative thinking as a result of the exposure to the use of the MIM.

The verbal forms of the TTCT contained 6 timed word-based activities which included asking the students to improve a product and provide unusual uses of a common item (Torrance, 1998a, b). The tests measured three elements of cognitive processes of creativity which are fluency (the number of meaningful and relevant responses), flexibility (the diversity of categories of the relevant responses), and originality (the uniqueness of the responses). All scorings were carried out based on the Scoring Workbook and Norms-Technical Manual (Torrance, 1998c).

Students' interview

A set of semi-structured interview questions in English for the students was also used (see Appendix). The purpose of the focus group interview was to find out students' opinions about the use of the MIM, and whether the MIM helped them in their learning or the development of creativity.

Procedures

The study was conducted in the first 5 weeks of the university term. In the first week, in a separate meeting with students during class time, the TTCT verbal form A was administered to all 27 students as a pretest. They then attended their normal weekly lectures (2 meetings x 1 hour), and a lab session (1 meeting x 2 hours). The exposure to the MIM began in the second week of the term in order to avoid the obstacles of the administration and students' registration.

Access to the MIM was during the lab session. Each student was provided with an individual computer and headset. Students were asked to spend the first 10-15 minutes of the class on the MIM, then they could continue with the normal activities during the lab session, which included solving case studies and working on their group project. However, they could refer back to the MIM whenever they needed to.

The TTCT verbal form B was administered in a separate session after the fourth lab session as a posttest.

Ten volunteer students were interviewed in two focus group interviews with each group consisting of five students.

DATA ANALYSIS

A mixed method approach to the research was used. The quantitative data from the TTCT were analyzed in two ways. Firstly, sample pretest results' for fluency, flexibility, originality, and the overall creativity scores were compared to the sample posttest results. Secondly, the mean scores of all the creative thinking performance as well as in the creative thinking elements.

A paired-samples t-test was conducted to evaluate the impact of using the MIM on students' scores on TTCT elements (fluency, flexibility, originality, and overall creative thinking scores). The quantitative data were then triangulated against the qualitative data from the focus group interview which provided more indepth information on their learning using MIM.

FINDINGS AND DISCUSSION

Table 1 illustrates descriptively that the posttest scores portrayed an upward trend when compared to the pretest scores for all the elements in the TTCT. All differences were significant. In addition, fluency shows the highest statistically significant increase from the pretest ($M = 77.15$, $SD = 7.466$) to the posttest ($M = 90.41$, $SD = 5.380$), $t(26) = -10.825$, $p <.005$ (two-tailed) compared to the other two elements (flexibility = -11.96, originality = -10.78). A slightly lower mean score difference was reported for the overall TTCT mean score (-12.00). This indicates that the number of answers provided by the students increased considerably, but the production of varied and novel answers was slightly lower. This is most probably attributed to the incongruence between the information represented in the MIM with the type of questions asked in the TTCT. The MIM presented information on concepts of engineering design whereas only two questions in the TTCT dealt with this theme (see Appendix for a sample of TTCT questions). We assumed that there is a high chance that students were not able to identify the appropriate schemas from the long-term memory as a result of utilizing the

TABLE 1

Paired samples statistics and test scores of the creative thinking elements and overall creative thinking score

Creative thinking		Pretest		Posttest		
	N	M	SD	M	SD	t-test
Fluency	27	77.15	7.466	90.41	5.380	-10.825**
Flexibility	27	77.56	6.302	89.52	5.041	-11.256**
Originality	27	83.07	11.913	93.85	8.075	-5.570**
Overall (Standard Score)	27	79.30	8.222	91.30	5.915	-8.978**

**$p \leq 0.05$

MIM to manage questions in the TTCT that did not deal with mechanical concepts. Stating so, we considered this to be one of the limitations of the study.

Nevertheless, Table 1 also illustrates that the t-test results exhibited a significance difference between the pretest and posttest for all the creative thinking elements and the overall TTCT result. Generally, such results support the earlier hypothesis that the utilization of MIM could increase engineering students' creative thinking. However, since there were no control groups for comparison, with the sample being tested, it should be noted that we cannot exclude that the difference could have been due to a different variable in the environment other than the MIM such as the nature of the syllabus content which require students to solve case studies which could trigger students' critical and creative thinking or the dynamics of students characteristics namely learning styles or motivational factors. Although previous studies in multimedia learning have not looked at creative thinking performance, there have been studies that have tested students' transfer performance.

Mayer (2001) states that transfer occurs in learning once students are able to understand the new information and transfer it to novel situations. This resonates with the definition of creativity (Amabile, 1998). Studies conducted by Mayer and his colleagues on the principles of CTMD, which use transfer tests showed that students performed better in the transfer test when the multimedia principle (Mayer and Anderson, 1992), contiguity principle (Mayer and Anderson, 1991: 1992), coherence principle (Harp and Mayer, 1998), and interactivity principle (Mayer and Chandler, 2001; Mayer et al., 2003) were effectively applied to the design of the multimedia materials the students used for learning. It should be noted that all the transfer tests in all these studies covered or inquired about the information that had been included in the multimedia presentation. Therefore, since creativity has been commonly defined not only in terms of creative cognitive process, but also as the production of creative ideas and creative products, a means of assessing the creativity of the engineering students in future studies should include assessing the production of engineering products in order to look for the effective transfer of the information represented in the MIM to their constructed products.

The results presented in Table 1 were also supported by the data collected in the focus group interview sessions. In the interviews, most of the students indicated that watching the MIM had helped them to understand engineering concepts better, and to apply the mechanism concepts to create novel ideas and products. Examples of these comments are shown below:

S2: The MIM stimulates students' critical thinking about design, and improve my understanding about the concepts. It helps the students to visualize the motion of the part easily and 100% correct.

S6: This multimedia file gives me a strong understanding, improve my skills, and give me new experience and new knowledge.

S10: I think the motion and graphics in the multimedia can help me to learn to create device which is new and more complicated.

This indicates that the design of the MIM based on four of the CTMD principles effectively elicited germane cognitive load, which in turn fostered students' understanding and learning. However, one student who was a high achieving student did not agree that the MIM had helped him to enhance his creative thinking; in fact, he stated that it could hinder students' imaginative skills.

S1: It can help the students to imagine the right motion and function of the mechanism, but I think it does not help the students to imagine on their own. It will prevent the students from generating their own imagination skills.

The student's comment indicates that it is worth considering that MIM could also hinder creativity. Some creativity theorists believe that imagination is one of the important factors in creative production (Rhodes, 1987) and generating creative ideas (Milgram, 1990).

Some individuals depend on and form their ideas using their imaginative skills. In the case of S1, although the MIM has helped him to understand the mechanism concept, it had prevented him from imagining creatively. In future studies, as mentioned above, students like S1 could make use of their imaginative potential in creating new and novel products. However, since imagination effect is not the focus of this particular study, this phase of the issue will not be discussed further.

It is generally known that the mechanical engineering industry is dominated by males. At the location where the study was conducted, the ratio of the male students to female students was 4:1. Therefore, it would be interesting to find out whether there were differences in the TTCT scores between the genders. Table 2 presents the mean scores for the TTCT results for both pretest and posttest differentiating between the genders.

Generally, Table 2 indicates that 1) the pretest and posttest mean scores of male students were higher than for the female students, and 2) there was an increase in the posttest mean scores for both male and female students for all the creative thinking elements and the overall TTCT results. However, the mean score difference indicates that female students scored higher than the male students for fluency (F = -14.14, M = -12.95), originality (F = -11.43, M = -10.55) and the overall TTCT results (F = -12.42, M = -11.85) whereas it is only for the flexibility mean score (M = -12.15, F = -11.43) that male students scored higher than the female students.

This indicates that the use of MIM has helped both male and female students to enhance their creative thinking in the different dimensions of

TABLE 2

Mean scores of the creative thinking elements and overall creative thinking score according to gender

Creative thinking	M Pretest		M Posttest	
	Female (n = 7)	Male (n = 20)	Female (n = 7)	Male (n = 20)
Fluency	73.86	78.30	88.00	91.25
Flexibility	75.86	78.15	87.29	90.30
Originality	79.14	84.45	90.57	95.00
Overall (Standard score)	76.29	80.35	88.71	92.20

creative thinking. The data appears to indicate that it has helped the female students more than the male students. However, there are limitations to the study that need to be considered: 1) the number of students in the sample, 2) the imbalance in numbers between the genders, and 3) the absence of a control group for the sample.

CONCLUSION

Generally, the findings of this study indicate that with appropriate design, the use of multimedia instructional materials may well help suppport creative thinking among engineering students. This in turn might help students to be creative in creating products or solving problems when the opportunities arise.

However, the study has highlighted a few limitations. These limitations and their implications for future studies are discussed below:

1) The design of this study involved only one experimental group of students with no control group for comparison. We suggest that control groups be included in future studies to test the engineering students' use of the MIM on their creative thinking.

2) The data gathered from this study is limited and relied solely on the TTCT results and students' interviews; therefore, we suggest that for future studies, these findings should be supported with transfer tests on the information represented in the MIM, or with the creation of products to measure product creativity. Since the MIM dealt with mechanism concepts, students could be asked to create products by utilizing the mechanism concepts learnt from the MIM.

In summarizing, it is possible that the design of MIM which considers appropriate load on the learner's cognitive system can ensure that new schemas are constructed, and therefore, allow cognitive interaction and manipulation between these new schemas and the existing schemas to produce novel and creative ideas.

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APPENDIX

Students' Interview Questions

The purpose of conducting the students' interview is to further understand their opinions on the use of multimedia instructional materials (MIM) and in what way have the MIMs helped them in their learning or the development of creativity

1. Do you know what creativity is? Can you define creativity?
2. What do you understand about creative thinking?
3. How frequently have you referred to the MIM during your lab session?
4. Can you generally describe your experience of using the MIM?

5. In your opinion, how have the MIM helped you with your learning and understanding?
6. Do you think using MIM has any positive impacts on your learning? Why? In what way has it affected you?
7. Do you think using MIM has any influences on your creativity? Why? In what way has it influenced you?
8. What are the characteristics of the MIM that has helped with your learning and your creativity?

Torrance Tests of Creative Thinking (TTCT) Sample Question

Unusual Uses (Tin Cans) Most people throw away their tin cans, but they have thousands of interesting and unusual uses. List as many of these interesting and unusual uses as you can.

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