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Logical Thinking Abilities among Form 4 Students in the Interior Division of Sabah, Malaysia

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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 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' logical thinking abilities based on their gender and science achievement at lower secondary level. This was a non-experimental quantitative research and sample survey method was used to collect data. Samples were selected by using a two-stage cluster random sampling technique. Independent samples t-test and one-way ANOVA were used to test the stated null hypotheses at a specified significance level, $\alpha = .05$*. Research findings showed that the overall mean of students' logical thinking abilities were low. The mean score in percentages for all the subscales (except conservational reasoning) were lower than the overall mean. This research also revealed that up to 98% of the respondents were categorized at the concrete operational stage whereas only 2% were categorized at the transitional stage. Research findings also found that there was no significant difference in the mean of logical thinking abilities (except for conservational reasoning) based on students' gender. Nonetheless, a significant difference based on their science achievement at lower secondary level was found. This research finding brings some meaningful implications to those who are involved directly or indirectly in the curriculum development and implementation of science curriculum especially at the rural secondary schools of Sabah, Malaysia.*

Key words: Logical thinking abilities; Conservational reasoning; Proportional reasoning; Combinatorial reasoning; Probabilistic reasoning; Correlational 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 level of schooling.

Cognitive Development Theory, a well-known theory proposed by Jean Piaget has conceptualised four different stages in the cognitive development of a person i.e. sensorimotor (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. 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 & Piaget, 1958; Lawson, 1982b, 1985; Linn, 1982) have 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 science and mathematics advanced courses at secondary level (Wilson & Wilson, 1984).

The Study

Problem Statement

The fundamental function of the schooling system in 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 & 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 teaching of facts and concepts which are specific to a particular knowledge 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 for secondary school are to provide students with the knowledge and skills in science and technology and enable them to solve problems and make decisions in everyday life based on scientific attitudes and noble values (Curriculum Development Centre, Ministry of Education Malaysia, 2001). Via the science curriculum, it is hoped that students will be able to acquire scientific skills (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 decision-making.

Based on the Cognitive Development Theory proposed by Jean Piaget, Form 4 students (16 years) are at the formal operational stage which 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 are determinants of students' success in science and mathematics advanced courses at secondary level (Wilson & Wilson, 1984). On the other hand, previous researchers (DeLuca, 1981; Hernandez, Marek, & Renner, 1984; Howe & Shayer, 1981; Meehan, 1984; Shemesh, 1990) have found significant difference in logical thinking abilities between male and female students. Male students performed better than female students in Piagetian formal reasoning tasks.

Nonetheless, not many documented researches have been conducted to gauge rural students' logical thinking abilities. Hence, the aim of this study is to gauge the 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 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 students' logical thinking abilities based on their gender and science achievement at lower secondary level.

Research Hypotheses

This research was guided by the following hypotheses:

Ho_1: There is no significant difference in the mean of logical thinking abilities based on students' gender;

Ho_2: There is no significant difference in the mean of logical thinking abilities based on students' science achievement at lower secondary level.

Methodology

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 were used to test the stated null hypotheses.

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.

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, Samples and Sampling Techniques

The populations of this study were 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 & Shevlin, 2001). Krejcie and Morgan suggested that for a 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 two Form 4 classes from each school by using the random number table. All the students in the chosen classes were automatically taken as the samples of the study. The combination of sampling techniques is to ensure the representativeness of the samples used in the study.

Research Instrument

Group Asssessment 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, Yeany, & Padilla, 1983) and 'Test of Logical Thinking' (TOLT) (Tobin & 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 (refer to the Appendix for sample item of each subscale).

Table 2
Distribution of Items According To Six Different Modes of Logical Thinking

Subcales	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

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 stated problem. Then, students were asked to choose the best justification for the chosen answer from a list of 2 to 5 possible justification. On the other hand, pictorial presentation was used to enhance better understanding of the items (Roadrangka *et al*., 1983).

Validity and Reliability of the Instrument

The researcher has examined all the items in the original GALT and TOLT instrument and found that most of the items were suitable to be used in Malaysian context. Efforts have been done to ensure the content and face validity of the modified and translated version of the instrument. In this matter, the items were translated into Malay language so that the respondents can understand the items and choose their best answers. The Cronbach's alpha reliability coefficient of the instrument was .52 which is considered moderate for use in the study.

Data Collection Procedures

Before administering the instrument, formal permission from the principals of the schools involved was sought and obtained. The instrument of this study was then administered by the researcher. In this matter, 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 (approximately 2 hours) to answer all the questions in the instrument.

Data Analysis Procedures

Descriptive statistics which include measures of central tendency (i.e. mean, and mean in percentage) and measures of variability (i.e. range, standard deviation, and standard deviation in percentage) were used to gauge logical thinking abilities among Form 4 students in the Interior Division of Sabah, Malaysia.

Students' answers on the instrument were checked and scored by researcher to ensure consistency in marking. 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 prepared to gauge students' combinatorial reasoning ability. One point will only be given if all the correct combination 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 Lawsan (1995), students' performance in GALT instrument can be used to categorise students into empirical-inductive thinking pattern (score 0 to 15) or hipothetical-deductive thinking pattern (score 16 to 21). On the other hand, students can also be categorised 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.

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

Research Findings and Discussion

Logical Thinking Abilities among Form 4 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.

Table 3
Mean and Standard Deviation of Logical Thinking Abilities (N = 549)

Subscales	No. of items	*M*	*SD*	*M%*	*SD%*	Range
Conservational reasoning	4	1.384	1.084	34.608	27.100	0 - 4
Combinatorial reasoning	3	.424	.619	14.147	20.640	0 - 3
Controlling variables	3	.368	.582	12.263	19.403	0 - 3
Correlational reasoning	3	.330	.582	10.990	19.383	0 - 3
Proportional reasoning	5	.516	.749	10.310	14.972	0 - 4
Probabilistic reasoning	3	.169	.463	5.647	15.417	0 - 3
Overall	21	3.191	2.158	15.197	10.274	0 - 12

Descriptive statistics in Table 3 showed that the overall mean of logical thinking abilities among Form 4 students in the Interior Division of Sabah is 3.191 (*M%* = 15.197) with a standard deviation of 2.158 (*SD%* = 10.274). The mean and standard deviation (in percentage) according to different modes of logical thinking abilities in descending order are: conservational reasoning (*M%* = 34.608, *SD%* = 27.100), combinatorial reasoning (*M%* = 14.147, *SD%* = 20.640), controlling variables (*M%* = 12.263, *SD%* = 19.403), correlational reasoning (*M%* = 10.990, *SD%* = 19.383), proportional reasoning

(*M*% = 10.310, *SD*% = 14.972) and, probabilistic reasoning (*M*% = 5.647, *SD*% = 15.417).

These research findings revealed that logical thinking abilities among Form 4 students in the Interior Division of Sabah were low with the mean score (in percentage) in the range of 5.6% to 34.6%. Mean scores in percentage for all the subscales (except conservational reasoning) were less than the overall mean of logical thinking abilities. Further analysis, based on Lawson's categories of cognitive development, surprisingly found that 98% of the respondents are categorised at the concrete operational stage whereas only 2% are categorised at the transitional operational stage. According to Lawson (1995), students can be categorised 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, mean score in percentage 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 mentioned above, 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 an education system which is more exam-orientated. Hence, less emphasis is given to the teaching and use of thinking skills. Science teaching and learning strategies are aligned to objectivism with the aim to cover the syllabus within the alloted time without 'investing' too much time to nurture thinking skills among students. Furthermore, school evaluation system which only emphasises the acquisition of content knowledge contributes 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% 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 of students in local higher learning institutions were reported as low. Syed Anwar Aly (2000) found that only 19% of matriculation college students possess high scientific reasoning abilities, 66% at medium stage whereas 15% possess low scientific reasoning abilities. In the same study, Syed Anwar Aly (2000) reported that only 19% of Malaysian students with average age of 19 years old possess high scientific reasoning abilities compared to 22% of American students with average age of 16 years old (Lawson *et al*., 1991).

Mean Difference in Logical Thinking Abilities Based on Students' Gender

Independent sample *t*-test results (Table 4) showed that there is no significant difference in the overall mean of logical thinking abilities based on students' gender. Thus, the first null hypothesis which stated that there is no significant difference in the means of logical thinking abilities based on students' gender is accepted.

Although male students ($M = 3.367$, $SD = 2.373$) scored higher than female students ($M = 3.044$, $SD = 1.949$) 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 $t = -2.222$ and $p = .027$.

Table 4
Independent Sample T-Test Results For Mean Difference in Logical Thinking Abilities Based On Gender (N = 549)

Subscales	Gender	*N*	*M*	*SD*	*t*	*df*	*p*
Conservational reasoning	Male	251	1.498	1.201	-2.222*	477.331	.027
	Female	298	1.289	.966			
	Overall	549	1.384	1.084			
Proportional reasoning	Male	251	.582	.777	-1.893	515.368	.059
	Female	298	.460	.720			
	Overall	549	.516	.749			
Controlling variables	Male	251	.387	.612	-.684	547	.495
	Female	298	.352	.557			
	Overall	549	.368	.582			

Subscales	Gender	*N*	*M*	*SD*	*t*	*df*	*p*
Probabilistic reasoning	Male	251	.163	.440	.281	547	.779
	Female	298	.175	.482			
	Overall	549	.169	.463			
Correlational reasoning	Male	251	.339	.627	-.331	547	.741
	Female	298	.322	.542			
	Overall	549	.330	.582			
Combinatorial reasoning	Male	251	.398	.601	.903	547	.367
	Female	298	.446	.635			
	Overall	549	.424	.619			
Overall	Male	251	3.367	2.373	-1.721	483.410	.086
	Female	298	3.044	1.949			
	Overall	549	3.191	2.158			

* $p < .05$

The finding of this study also surprisingly revealed that up to 97.2% of male respondents and 98.7% of female respondents are categorised at concrete operational stage whereas the remaining are categorised at transitional operational stage. This finding was found 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, found that there is no significant difference in the ability of conservation of length between male and female students. On the other hand, this finding was contradicting with previous researchers (DeLuca, 1981; Hernandez, Marek, & Renner, 1984; Howe & Shayer, 1981; Meehan, 1984; Shemesh, 1990). Previous researches have found a significant difference in logical thinking abilities between male and female students. Male students performed better in Piagetian formal reasoning tasks compared to female students.

Mean Difference in Logical Thinking Abilities Based on Students' 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 mean 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 ($F(2, 496) = 19.497$, $p < .0005$), 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.

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			

* $p < .05$

Post-Hoc Tukey HSD multiple comparison results (Table 6) 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.

Table 6
Post-Hoc Tukey 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)	-

Subscales	Science achievement at lower secondary level	*N*		Low	Medium	High
			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)	-

* $p < .05$

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

Previous researches (e.g. Bitner, 1991; Boulanger & Kremer, 1981; Hofstein & Mandler, 1985; Howe & Durr, 1982; Keig & Rubba, 1993; Krajcik & Haney, 1987; Lawson *et al.*, 1975; Lawson, 1982a, 1982b; Marek, 1981; Mitcell & Lawson, 1988; Piburn, 1980; Piburn & Baker, 1989; Roadrangka, 1995; Siti

Hawa Munji, 1998; Staver & 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 has provided concrete evidence that formal reasoning abilities can 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 scores 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 & 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, Sadler & Loehr, 2005, Lewis & Lewis, 2007). For instance, Lewis and Lewis (2007) emphasised 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.

Implication of the Study

In the effort to develop students' logical thinking abilities, some changes in terms of the evaluation system and science teaching and learning strategies need to be seen intentionally. In relation to this, different areas such as planning and developing instructional programmes, 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 & Renner, 1980; Moshman & Thompson, 1981; Akdeniz, 1993; Çepni & 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 really 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. Further, 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 & 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 schooling system is not meant for 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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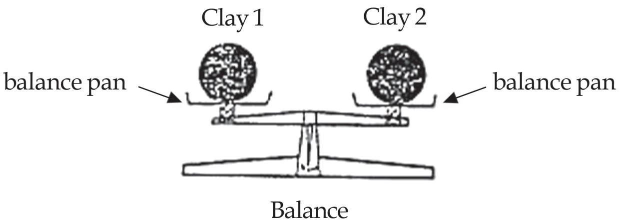
Appendix

Conservational Reasoning

ITEM 1: PIECE OF CLAY

Tom has two balls of clay. They are the same size and shape. When he places them on the balance, they weigh the same.



The balls of clay are removed from the balance pans. Clay 2 is flattened like a pancake.

WHICH OF THESE STATEMENTS IS TRUE?

A) The pancake-shaped clay weighs more.

B) The two pieces weigh the same.

C) The ball weighs more.

REASON

1) You did not add or take away any clay.

2) When clay 2 was flattened like a pancake, it had a greater area.

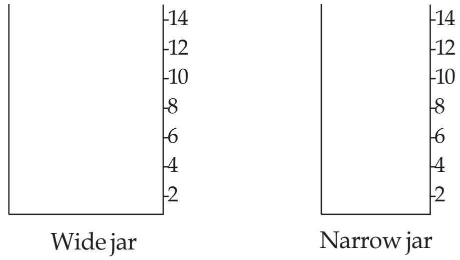
3) When something is flattened, it loses weight.

4) Because of its density, the round ball had more clay in it.

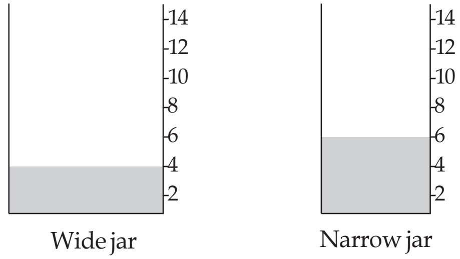
<u>Proportional Reasoning</u>

ITEM 5: PLASTIC JAR #1

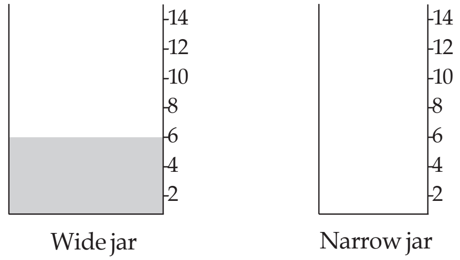
There are two plastic jars, one wide and one narrow.



Each has equally spaced marks along the side. Danny pours the same amount of water into each jar. The water level comes up to the 4th mark in the wide jar and to the 6th mark in the narrow jar.



He pours a larger glass of water into the wide jar. The water level comes up to the 6th mark.



HOW HIGH WOULD THE SAME AMOUNT OF WATER COME IF IT WERE POURED INTO THE NARROW JAR?

A) 6 2/3

B) 8

C) 9

D) other

REASON

1) If you pour the same amount of water in the wide and narrow jars, the ratio will always be 2 to 3.

2) If the water level is 6 in the wide jar, it will be two more in the narrow jar.

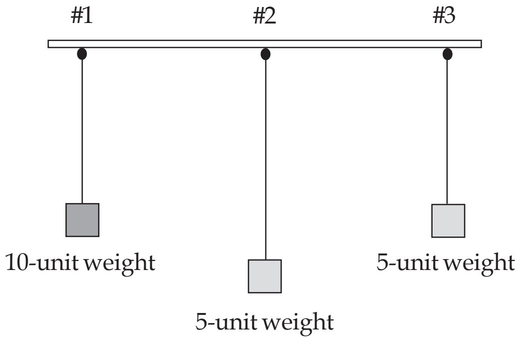
3) The ratio of water in the wide and narrow jars is 2 to 3. If the water level is 6 in the wide jar, it will be 2/3 more in the narrow jar.

4) There is no way of predicting.

Controlling variables

ITEM 10 : PENDULUM LENGTH

Three strings are hung from a bar. String #1 and #3 are of equal length. String #2 is longer. Charlie attaches a 5-unit weight at the end of string #2 and at the end of string #3. A 10-unit weight is attached at the end of string #1. Each string with a weight can be swung.



Charlie wants to find out if the length of the string has an effect on the amount of time it takes the string to swing back and forth.

WHICH STRING AND WEIGHT WOULD HE USE FOR HIS EXPERIMENT?

A) string #1 and #2

B) string #1 and #3

C) string #2 and #3

D) string #1, #2 and #3

E) string #2 only

REASON

1) The length of the strings should be the same. The weights should be different.

2) Different lengths with different weights should be tested.

3) All strings and their weights should be tested against all others.

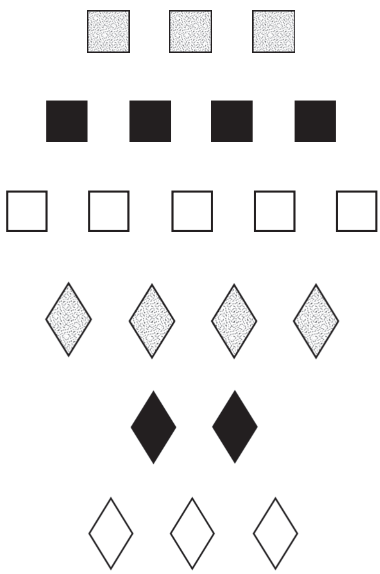
4) Only the longest string should be tested. The experiment is concerned with length not weight.

5) Everything needs to be the same except the length so that you can tell that the length makes a difference.

<u>Probabilistic Reasoning</u>

ITEM 13 : SQUARES AND DIAMONDS #1

In a cloth sack, there are



3 spotted wooden squares

4 black wooden squares

5 white wooden squares

4 spotted wooden diamonds

2 black wooden diamonds

3 white wooden diamonds

All of the square pieces are the same size and shape. The diamond pieces are also the same size and shape. One piece is pulled out of the sack.

WHAT ARE THE CHANCES THAT IT IS A SPOTTED PIECE?

A) 1 out of 3

B) 1 out of 4

C) 1 out of 7

D) 1 out of 21

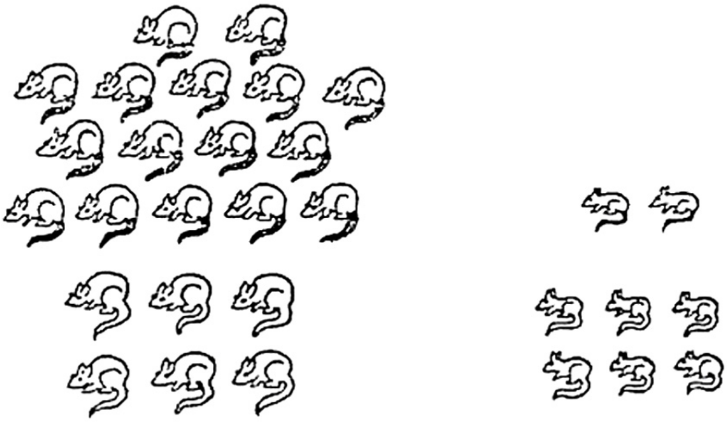
E) other

REASON

1) There are twenty-one pieces in the cloth sack. One spotted piece must be chosen from these.
2) One spotted piece needs to be selected from a total of seven spotted pieces.
3) Seven of the twenty-one pieces are spotted pieces.
4) There are three sets in the cloth sack. One of them is spotted.
5) ¼ of the square pieces and 4/9 of the diamond pieces are spotted.

Correlational Reasoning

ITEM 16 : THE MICE # 1



A farmer observed the mice that lived in his field. He found that the mice were either fat or thin. Also, the mice had either black tails or white tails.

This made him wonder if there might be a relation between the size of a mouse and the colour of its tail. So, he decided to capture all of the mice in one part of his field and observe them. The mice that he captured are shown above.

DO YOU THINK THERE IS A RELATION BETWEEN THE SIZE OF THE MICE AND THE COLOUR OF THEIR TAILS (THAT IS, IS ONE SIZE OF MOUSE MORE LIKELY TO HAVE A CERTAIN TAIL COLOUR AND VICE VERSA)?

A) Yes

B) No

REASON

1) 8/11 of the fat mice have black tails and ¾ of the thin mice have white tails.

2) Fat and thin mice can have either a black or a white tail.

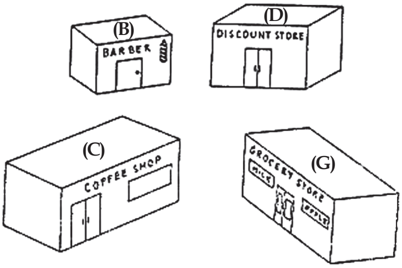
3) Not all fat mice have black tails. Not all thin mice have white tails.

4) 18 mice have black tails and 12 have white tails.

5) 22 mice are fat and 8 mice are thin.

<u>Combinatorial Reasoning</u>

ITEM 19 : THE SHOPPING CENTER



In a new shopping center, 4 stores are going to be placed on the ground floor. A barber shop (B), a discount store (D), a grocery store (G), and a coffee shop (C) want to locate there.

One possible way that the stores could be arranged in the 4 locations is BDGC which means the barber shop first, the discount store next, then the grocery store and the coffee shop last.

LIST ALL THE OTHER POSSIBLE WAYS THAT THE STORES CAN BE LINED UP IN THE FOUR LOCATIONS.