RELATIONSHIP BETWEEN SCIENCE PROCESS SKILLS AND LOGICAL THINKING ABILITIES OF MALAYSIAN STUDENTS

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The study of science involves learning both processes as well as content. While science process skills represent possible problem-solving mechanisms involved in any cognitive process, the use of logical thinking abilities enables us to develop scientific knowledge. This article will discuss the findings from a study designed to investigate the relationship between science process skills and logical thinking of upper secondary students in Malaysia. The science process skills were assessed by the Test of Integrated Process Skills utilizing a multiple-choice format. The Group Assessment of Logical Thinking was used to assess the Piagetian cognitive reasoning level of the students and their performance on the six Piagetian cognitive modes. The findings from the study gave some indication on the level of competency in the science process skills and the level of logical thinking and the extent to which the intended science curriculum was achieved.

INTRODUCTION

One of the most important and pervasive goals of schooling is teaching students to think. Teachers teaching all school subjects should strive to accomplish this goal. Science, with its emphasis on hypothesizing, manipulating certain conditions in the physical world and reasoning from data, provides a means whereby the individual can think in a logical way about everyday events and phenomena and solve practical problems. Science is an active enterprise that involves observing what is happening in the real world and trying to make sense out of it through models and theories about how the world and its attendant features work. Science has since become a major focus in our lives. Today increased attention is paid to showing the public the role of science in our everyday lives. Teachers want their students to have positive attitudes toward science and to value contributions from science. They want the children to develop scientific literacy so that their students will begin to think like scientists and understand how scientific theories are constructed and tested (Arons, 1983).

Science is both content (what we know) and process (how we find out). Learning science successfully requires students to acquire both declarative knowledge (knowledge about something) and procedural knowledge (knowledge of how to do something). Declarative knowledge consists of facts, principles, concepts, theories and laws that can be told to others. Basically, it is about 'what is.' Procedural knowledge on the other hand is needed 'to do and experience science.' Procedural knowledge is our knowledge of how to perform various physical and intellectual tasks. Procedural knowledge is learned by doing something with declarative knowledge, such as drawing inferences, constructing classifications, or making generalizations from facts available in the declarative knowledge system. Procedural knowledge can be used to interpret new situations, solve problems, think and reason in challenging and unknown areas. In science, procedural knowledge is both needed in and constructed from hands-on/minds-on tasks.

Scientists and educators generally agree that the best way for children to learn science is through an active minds-on/hands-on approach that involves them in observing, measuring, predicting, inferring, investigating, and explaining the world in ways that parallel the methods of scientists. By structuring lessons to provide 'hands on' time and 'messing around' time, teachers hope to stimulate students' understanding of science as a process of discovery and not just a body of facts.

Various terms have been used to describe these science process skills. These include the scientific method, scientific thinking and critical thinking. Science process skills have been defined as a set of broadly transferable abilities, appropriate to many science disciplines and reflective of the behavior of scientists. Science—A Process Approach (SAPA) grouped science process skills into two types—basic and integrated. The basic (simple) process skills provide a foundation for learning the integrated (more complex) skills.

Numerous research projects have focused on the teaching and acquisition of basic skills. Studies focusing on the Science Curriculum Improvement Study (SCIS) and SAPA indicate that elementary school students, if taught process skills abilities, not only learn to use those processes, but also retain them for future use (Burns, Okey & Wise, 1985). Further study of experimenting abilities shows that they are closely related to the formal thinking abilities described by Piaget. In fact, one of the ways that Piaget decided whether someone was formal or concrete was to ask that person to design an experiment to solve a problem (Padilla, 1990). Children construct knowledge by doing science. Doing science means applying the processes that form the core of inquiry-based, hands-on science learning. These activities 'lead children to the facts, principles, laws and generalizations which scientists have established' (Renner & Marek, 1990. p. 243). However, to apply the processes, children have to master them.

Science is offered to Malaysian students beginning from Year Four at the elementary level and continues on up to Form Five at the secondary level. The emphasis is on mastery of content, acquisition of scientific skills and inculcation of noble values, including the development of scientific attitudes. Furthermore, science contributes its unique skills, with its emphasis on hypothesizing, manipulating the physical world and reasoning from data towards the development of critical and creative thinking in students. Among the science process skills listed in the curriculum are: observing, classifying, measuring and using numbers, inferring, predicting, communicating, using space/time relations, interpreting data, defining operationally, recognizing and controlling variables, formulating hypotheses and experimenting.

Padilla (1990) put forth three strong arguments that stress on the need and importance for including science process skills activities in classroom learning. One is the generalizability of these skills to life. Secondly, process skills activities more accurately reflect the nature of science and what scientists do. Thirdly, process skill activities involve the development of formal reasoning abilities. The stimulation of students' formal reasoning or thinking abilities represents another worthwhile aim of science education.

Raven (1974) indicated the acquisition and comprehension of science concepts correspond to the use of logical operations that has long been studied by Piaget and his colleagues.

According to Piaget (1972), there are four stages in the growth of logical thinking from infancy to adolescence. The stages, sensory-motor (ages 0-2 years), preoperational (age 2-7 years), concrete operational (age 7-11 years), and formal operational (age 11-16 years), represent a progressive organization and reorganization of experiences to form mental structures capable of accommodating new material and utilizing it. The essential difference between one stage and another is a difference in the child's mode of thinking. The modes of thinking that a formal student should be able to perform are: hypothetical-deductive reasoning, reflective thinking, reasoning with proportions and ratios, controlling of variables in an experiment, syllogistic reasoning, abstract reasoning, comprehension of allegory, performance of second order operations and formulation of theories.

Some researchers have developed reliable and valid classroom tests of cognitive developments. The first category consists of totally paper-and-pencil tests (e.g. Tobin & Capie, 1981). The second category includes some form of demonstration or manipulation of Piagetian based apparatus within a paper-and-pencil test format (Lawson, 1978). Several standard tasks developed by Piaget have been used extensively to assess the level of students' logical thinking abilities. These tasks are problem oriented and usually challenge a subject's ability to identify and control variables, use operational thought, apply prepositional logic, and/or use combinatorial reasoning abilities (Padilla, 1990).

Several studies (Tobin & Capie, 1981; Padilla, Okey & Dillashaw, 1983) have shown that there is a strong correlation between process skills achievement and an individual's formal reasoning ability. According to Gagne (1965) process science skills represented the generic skills observed in scientific investigations and these skills are transferable to other disciplines or subjects. Okey (1972) suggested that teaching students to process information should be among the main aims of education. He went on to add that process science skills are useful in training students to use their knowledge both in and out of the classrooms.

PURPOSE OF THE STUDY

The purposes of the study were: (i) to identify science process skills and thinking abilities of upper secondary students in Malaysia and (ii) to investigate the relationship between science process skills and logical thinking.

METHODOLOGY

The variables that were investigated in this study were the science process skills and logical thinking abilities of upper secondary Malaysian students. The science process skills were assessed by the Test of Integrated Process Skills (TIPS) developed by Burns, Okey and Wise (1985). The test used a multiple-choice format and the items were translated into Bahasa Melayu for local consumption. TIPS measures the students' performance on five of the following integrated science process skills: identifying variables, identifying hypotheses, defining operationally, designing experiments, and graphing and interpreting data.

The Group Assessment of Logical Thinking (GALT) was developed by Roadrangka (1985). GALT was uses to assess the Piagetian cognitive reasoning level of the students and the performance on the six Piagetian cognitive modes: conservation, proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning giving a total of 12 items. The test used a multiple-choice format for presenting options for answers as well as justification of reasons for the answers. The GALT was also translated into Bahasa Melayu.

SAMPLE

A total of 268 students took the two paper-and-pencil tests. A total of 218 students were from mixed (boys and girls) schools while the remaining students were from an all-girls school. Table 1 shows the characteristics of students involved in this study. Of the total, about 37.3 % (100 students) were from the science stream and all the students were in Form Four (average age 16 years) when the tests were conducted. The school science teachers administered the two tests and students were given two periods (120 minutes) to complete the two tests. A brief introduction and explanation of the tests were given by the teachers before the students started the tests.

Table 1
Sample characteristics

Type of schools	
Mixed (boys and girls)	218 (81.3%)
All Girls	50 (18.7%)
Gender	
Boys	106 (39.6%)
Girls	162 (60.4%)

ANALYSES

The two tests were checked for the correct responses given by the students. The scores were: right = 1, and wrong = 0 for the TIPS items giving a maximum score of 36. For the items in GALT, there were two answers for each of the first 18 items. It was coded as '1' if both answers of each item were correct. Otherwise, it was coded as '0'. The last three items related to combinatorial reasoning were coded '1' only if all possible combinations were written in the blanks. Otherwise, they were coded as '0'. The maximum score possible was 12.

RESULTS AND DISCUSSION

The mean level science process skill ability for the sample was a score of 17.69 out of a possible 36 points. The order of science process skill abilities for the students was 'Interpreting data and graphing' (71.13%), 'Designing investigations' (51.92%), 'Defining operationally' (49.98%) and 'Identifying and formulating hypotheses' (47.98%) and 'Identifying variables' (37.78%) (see Table 2).

Table 2
Descriptive statistics of science process skill achievement for total number of students

Skills	No. of items	Mean	%
Identifying variables	12	4.54	37.78
Operationally defining	6	3.0	49.98
Identify and formulate hypotheses	9	4.32	47.98
Designing investigations	3	1.56	51.92
Interpreting data & graphs	6	4.27	71.13
TOTAL	36	17.69	49.14

The order (as estimated by 'proportion of students in answering each item correctly') of science process skill achievement by the students were:

Interpreting data and graphs

Designing investigations

Operationally defining

Identify and formulate hypotheses

Identifying variables

The percentage of correct responses ranged from 85.4% on item 11 (interpreting data and graphing), to 6.30% on item 27 (identify and formulate hypotheses). The findings showed that the percentage of correct responses were particularly low on items pertaining to 'identifying variables.' Except for item 3 which had 78.4% correct response, the percentage of correct responses for the other items ranged from 21.6% to 47.0%. The students performed better on items related to 'interpreting data and graphing' with percentages of correct responses ranging from 59.7 % to 85.4%.

The results implied that Malaysian students are capable of achieving the highest level in the sequence of science process skills, 'Interpreting data and graphing.' It is assumed that in order to do well at the highest level, students would have acquired the skills in identifying variables, defining operationally, identify and formulate hypotheses and designing investigations. However, this was not the case with this group of students. Most of them still had problems identifying variables as shown by the percentage of correct responses to the relevant items.

The good performance shown on items pertaining to 'interpreting data and graphing' could be due to the fact that Malaysian students had sufficient practice in such activities. The learning and understanding was also reinforced through the teaching of mathematics. However, in the teaching of science, teachers seldom mentioned the variables to be investigated. Except for explaining the purposes and readings to be taken, the concept 'variable' was not thoroughly explored during the practical sessions.

Table 3 shows the mean student performance on the Group Assessment of Logical Thinking (GALT). The mean score for the entire group of students was 2.89 out of the possible 12. The students seemed to have difficulty answering almost all of the questions. The percentage of correct responses for the items ranged from 3.4% for item 18 (correlational reasoning), to 57.5% for item 1 (conservation). Most of the students seemed to have difficulty in choosing the correct reasons for their answers.

Table 3
Descriptive statistics of GALT for total students

Skills	No. of items	Mean	%	% correct
Conservation	2	0.86	43.5	1. 57.5 2. 29.5
Proportional reasoning	2	0.52	25.8	3. 35.1 4. 16.6
Controlling variable	2	0.62	31.2	5. 33.2 6. 29.1
Probabilistic reasoning	2	0.25	12.5	7. 9.7 8. 15.3
Correlational reasoning	2	0.12	5.8	9. 8.2 10. 3.4
Combinatorial reasoning	2	0.51	25.2	11. 34.7 12. 16.8
TOTAL	12	2.89	24.1	

The students performed better on items pertaining to 'conservation' as compared to their performance on all other items. The students' performance indicated that one of the aims of the science curriculum at the elementary and secondary schools, i.e. to develop thinking skills, had yet to be achieved. The teaching of science should be planned in such a manner that would allow for students to reason out things for themselves using the process science skills. More opportunities should be provided to stimulate students' learning and thinking.

The percentage of students who answered correctly on items 9 and 10 was significantly lower than that of other items. Both items were categorized in a 'correlational reasoning' mode. Most of them selected verbal statements in response to these two items. The results exposed some weaknesses in the students' logical thinking abilities.

The correlation between science process skills achievement and logical thinking abilities was r = 0.5994 (see Table 4). The results indicated that if the student's score on the science process skills achievement is high, then the corresponding score on GALT should also be high. The correlation is slightly lower than the reported correlations from U.S. studies and higher than the correlation reported for Taiwan (Hsiung & Yeany, 1987). Many U.S studies reported correlations greater than 0.6 while Taiwan reported a correlation of 0.38. The differences may be due to instructional emphases and cultural factors.

Table 4
Pearson's Product-Moment Correlation Coefficient for science process skills achievement and GALT

	Process science skills	**GALT**
Process science skills	1.0000	0.5994
GALT	0.5994	1.0000

CONCLUSION

The acquisition of science process skills is one of the objectives stated in the science curriculum at the elementary as well as the secondary level. In addition, the science curriculum is developed with the aim of developing the students' creative and critical thinking skills. Both the science process skills and the thinking skills are interrelated. It is hoped that through active learning in science, students are able to acquire both the process skills as well as develop their thinking skills.

The principal purpose of this study was to identify science process skills and thinking abilities of upper secondary students in Malaysia and to investigate the relationship between science process skills and logical thinking. The findings showed that the students have attained certain science process skills particularly graphing and interpreting data. However, they have problems with the 'lower' level skills such as identifying variables and identifying and stating hypotheses. Similarly, they performed well on certain items in the group assessment of logical thinking especially that pertaining to 'conservation.' However, the overall performance in the science process skills and GALT were not satisfactory. In addition, the findings showed that there is a correlation between science process skills achievement and logical thinking skills.

Steps should be taken to improve Malaysian students performance in science, both content and process. Students also need to be exposed to more challenging tasks so that they can develop their skills. However, before embarking on any major activities, it is wise that teaching be well planned so that students are taught the basic skills necessary for any major tasks. Teachers play an important role in the students' learning. Teachers are required to provide a learning environment that would stimulate students' interests in science as well as to challenge their thinking. While it is recognized that teaching the science content in greater depth at each level/ year is important, it is also necessary for students to learn inquiry processes associated with doing science. By structuring lessons to provide 'hands on' time and 'messing around' time, teachers hope to stimulate students' understanding of science as a process of discovery and not merely to acquire facts.

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