THE INFLUENCE OF SCIENCE PROCESS SKILLS, LOGICAL THINKING ABILITIES, ATTITUDES TOWARDS SCIENCE, AND LOCUS OF CONTROL ON SCIENCE ACHIEVEMENT AMONG FORM 4 STUDENTS IN THE INTERIOR DIVISION OF SABAH, MALAYSIA

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The purpose of this study was to examine the direct and indirect effects of science process skills, logical thinking abilities, attitudes towards science, and locus of control on science achievement among Form 4 students in the Interior Division of Sabah, Malaysia. Research findings showed that there were low to moderate, positive but significant correlation among science process skills, logical thinking abilities, attitudes towards science, locus of control, and science achievement for all respondents. The research findings bring some meaningful implications to those who are involved directly or indirectly in the research and development of science education and training of science teachers especially in the Interior Division of Sabah, Malaysia.

KEY WORDS: science process skills, logical thinking abilities, attitudes towards science, locus of control, science achievement.

Background of the Study

The progressiveness of a nation is very much dependent on the generation of new ideas which will act as a catalyst to the development of the nation. In an effort to achieve the status of a developed nation, the Malaysian government had initiated and documented a vision (i.e. Vision 2020) to be achieved by the year 2020. The sixth strategic challenge identified is to establish a scientific and progressive society, a society that is innovative and forward-looking, one that is not only a consumer of technology but also a contributor to the scientific and technological civilisation of the future (Wan Mohd. Zahid, 1993). The core of this vision requires Malaysians to possess high scientific and technological skills to enable the people to be involved directly and indirectly in the up-stream and down-stream of science and technology activities.

The most fundamental and powerful human resource is intelligence where it is important not only to have a good brain but also to have the ability to use it and to ensure it is functioning effectively. Science has prepared ways which enable us to think logically about daily events and practical problem solving. Science also represents ways of organising knowledge which will then contribute to the development of cultures and intellect. To achieve this aim, the concept of education through science becomes imperative.

Two important fields of study in science education are science process skills and logical thinking abilities. Science process skills represent problem-solving mechanisms involved in any cognitive processes whereas logical thinking abilities are crucial in the acquisition and understanding of science concepts. Scientific knowledge is believed to develop via the use of science process skills and logical thinking abilities. On the other hand, researchers in science education also have emphasised the importance of attitude toward science and locus of control as variables to influence students' science achievement (e.g., Cannon & Simpson, 1985; Crandall & Crandall, 1983).

The Study

Problem Statement

Malaysia took part in the 'Third International Mathematics and Science Study – Repeat, TIMSS-R' (1997 - 2000) organised by the International Association for the Evaluation of Educational Achievement (IEA). As many as 38 countries from all over the world took part in this study. In Malaysia, the study was conducted in October 1998 and 5,713 Form Two students at average 14.4 years old were involved as respondents. Some of the important results were as follows:

1. Malaysia was in the 22nd place for science with average score 492. This score was not significantly different from the international average score, 488;
2. Malaysians students' overall performances in science were low for all benchmarks as compared to countries like Singapore, Japan, Australia, the United States of America and England; and
3. Malaysia was in the 19th place for the topics 'Environmental issues and natural resources'; 21st place for 'Scientific inquiry and properties of science'; 22nd place for 'Earth science' and 'Physics', and 24th place for 'Life sciences' and 'Chemistry'.

Based on the TIMSS-R (Ministry of Education, 2000) results, several issues emerged which need to be addressed. Some of the issues are: Why were Malaysian students' science achievement not satisfactory as compared to students from other countries such as Chinese Taipei, Singapore, Japan, Korea, Hong Kong, and Belgium? In the Malaysian context, a variety of science teaching and learning approaches namely scientific skills and thinking skills have been introduced via the revised science curriculum from time to time. Are students' science achievements influenced by their science process skills and logical thinking abilities? To what extent do science process skills, logical thinking abilities, attitudes toward sciences, and locus of control contribute to the acquisition and learning of science concepts among the students?

Research Objectives

The objectives of this research were:

1. to identify the possible linear relationships among science process skills, logical thinking abilities, attitudes towards science, locus of control, and students' science achievement;
2. to ascertain whether logical thinking abilities, attitudes towards science, and locus of control can predict students' science process skills;
3. to ascertain whether science process skills, logical thinking abilities, attitudes towards science, and locus of control can predict students' science achievement; and
4. to propose a direct and indirect effects structural model to predict students' science achievement based on science process skills, logical thinking abilities, attitudes towards science, and locus of control.

Research Hypotheses

This research was guided by the following four hypotheses:

Ho_1: There is no significant linear relationship among students' science process skills, logical thinking abilities, attitudes towards science, locus of control, and science achievement;

Ho_2: All the regression coefficients for logical thinking abilities, attitudes towards science, and locus of control are equal to zero when students' science process skill is the dependent variable;

Ho_3: All the regression coefficients for science process skills, logical thinking abilities, attitudes towards science, and locus of control are equal to zero when students' science achievement is the dependent variable;

Ho_4: All the path coefficients for science process skills, logical thinking abilities, attitudes towards science, and locus of control are equal to zero when students' science achievement is the dependent variable.

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. Multivariate analyses which include Pearson product-moment correlation, multiple regression, and path analysis were used to test the null hypotheses.

Location of the Study

This study was conducted in 18 Form Four classes from nine secondary schools in the Interior Division of Sabah, Malaysia in July-September, 2004.

Research Samples and Sampling method

The population of this study comprised Form Four students from 22 secondary schools in the Interior Division of Sabah, Malaysia who took Integrated Curriculum for Secondary School (ICSS) - Science as one of their compulsory learning subjects in school. Approximately 3,500 students formed the population of this study.

The sample size was determined based on the formula suggested by Krejecie and Morgan (1970) and power analysis (Miles & Shevlin, 2001). Krejecie and Morgan (1970) suggested that for a population between 3,000 and 3,500 a minimum sample of 341-346 is acceptable (p.608). Specifically, a two-stage cluster random sampling method was used to identify schools and Form Four classes which took part in this study. Listwise deletion method was used to determine the exact number of students involved in this study. Therefore only those respondents who have completed all six instruments were counted in the sample. As a result, a total of 400 students formed the sample in this study.

Instrumentation

Instruments used for collecting quantitative data in this study were translated and modified from the instruments as listed below while the Science Achievement Test (SAT) was self-developed by the researcher based on the syllabus and curriculum specification of ICSS-Science.

(i) Basic Science Process Skills Test (BSPST)(Padilla, Cronin, & Twiest, 1985);

(ii) Integrated Science Process Skills Test (ISPST)(Burns, Okey, & Wise, 1985);

(iii) Group Assessment of Logical Thinking Abilities (GALT)(Roadrangka, Yeany, & Padilla, 1983; Tobin & Capie, 1981);

(iv) Attitude Toward Science In School Assessment (ATSSA)(Germann,1988);

(v) Intellectual Achievement Responsibility Questionnaire (IAR)(Crandall, Katkovsky & Crandall, 1965);

(vi) Science Achievement Test (SAT).

Table 1 provides a brief description of the instruments' reliability – the number of items for each instrument and its alpha reliability scores for both the original and the adapted instruments.

Table 1
Number of Items and Alpha Reliability Scores of the Original and Modified Instruments

Instrument/Aspect	Original		Present Study	
	items	reliability	items	reliability
Basic Science Process Skills Test (BSPST)	36	.82	36	.67
Integrated Science Process Skills Test (ISPST)	36	.86	40	.72
Group Assessment of Logical Thinking Abilities (GALT)	21	.85	21	.52
Attitude Toward Science In School Assessment (ATSSA)	14	.95	14	.68
Intellectual Achievement Responsibility Questionnaire (IAR)	34	.66	30	.65
Science Achievement Test (SAT)	NA	NA	45	.66

Data Collection Procedures

Before administering the questionnaires, formal permission from the principals of the schools involved was sought and obtained. The instruments of this study were administered by the researcher. Students were gathered in the school hall and the instruments were administered to the students concurrently. The students were told about the nature of the questionnaire and how the questionnaires should be answered.

Data Analysis Procedures

In an effort to ensure all the collected data were normally distributed, graphical measures such as histogram, stem-and-leaf plot, Q-Q plot and detrended Q-Q plot had been plotted for each variable studied. Furthermore, numerical measures namely skewness and kurtosis measures were also used to identify any deviations from normal distributions (Hair, Anderson, Tatham, & Black, 1998; Miles & Shevlin, 2001). After the assumptions of using parametric techniques in analysing quantitative data were met, multivariate analyses which include Pearson product-moment correlation, multiple regression analysis, and path analysis were used to test null hypotheses at a specified significance level, $p < .05$.

Pearson Product-Moment Correlation

Correlation was used to identify significant linear relationships among science process skills, logical thinking abilities, attitude toward science, locus of control, and students' science achievement. Pearson product-moment correlation coefficients (r) were calculated to show the strength of the linear relationships among variables studied.

Multiple Regression Analysis

Stepwise multiple regression analysis was used to ascertain whether science process skills (Process), logical thinking abilities (Logic), attitude toward science (Attitude), and locus of control (Locus) could make significant predictions on students' science achievement (Science). Stepwise variables selection method was used in order to obtain a parsimonious model which can explain most of the variance in the dependent variable by using the least number of independent variables. Assumptions namely normality, homoscedasticity, linearity, and independence were met prior to multiple regression analysis. On the other hand, distance statistics (leverage measure and Cook distance) and influence statistics (DfBeta and DfFit) were used to identify any outliers and influential observations in the collected data. To detect multicollinearity among the independent variables used in this study, correlation matrices, Tolerance (T) and Variance Inflation Factor (VIF) were used (Hair *et al*., 1998).

Structural Equation Modeling

Structural Equation Modeling (SEM) is a multivariate technique combining aspects of multiple regression (examining dependence relationships) and factor analysis (representing unmeasured concepts – factors – with multiple variables) to estimate a series of interrelated dependence relationships simultaneously (Hair *et al*., 1998).

AMOS 4 Path Analysis

AMOS 4 path analysis technique was used to identify direct and indirect relationships among science process skills, logical thinking abilities, attitude toward science, locus of control, and students' science achievement. On this matter, logical thinking abilities (Logic), attitude toward science (Attitude), and locus of control (Locus) acted as exogenous variables whereas science process skills (Process) and students' science achievement (Science) played the role of endogenous variables.

Research Findings and Discussion

Linear Relationships among Science Process Skills, Logical Thinking Abilities, Attitude toward Science, Locus of Control, and Students' Science Achievement

The first null hypothesis was tested by using Pearson product-moment correlation at a specified significance level, $p < .05$. Correlation analysis results showed that there was low to moderate, positive and significant correlation among science process skills, logical thinking abilities, attitude toward science, locus of control, and students' science achievement. Pearson product-moment correlation coefficients were found in the range of .125 to .582 (See Table 2). Thus the first null hypothesis was rejected. However, it was found that there were low and not statistically significant correlations between attitudes towards science and locus of control with logical thinking abilities.

Table 2
Pearson Product-Moment Correlation Results (N = 400)

Variables	Process	Logic	Attitude	Locus	Science
Process	1.000				
Logic	.472**	1.000			
Attitude	.183*	-.035	1.000		
Locus	.125*	.033	.289**	1.000	
Science	.582**	.355**	.129*	.136**	1.000

* $p < .05$; ** $p < .01$

These findings were consistent with related previous researches (e.g., Cannon & Simpson, 1985; Germann, 1988; Haladyna, Olsen, & Shaugnessy, 1982; Kalechstein & Nowicki, 1997; Padilla, Okey, & Garrard, 1984; Roadrangka, 1995; Tobin & Capie, 1982). For instance, research done by Haladyna *et al*. (1982) found that students' attitudes towards science were closely related to students' perceptions on the importance of science and their fatalism level. Related researchers (e.g., Shaugnessy, Haladyna, & Shaugnessy, 1981; Haladyna, 1982; Haladyna & Shaugnessy, 1982) showed that positive attitudes towards science and other school subjects can be related to students' perceptions on their learning ability. Students' self-efficacy was positively correlated with their attitudes towards science whereas students' fatalism levels were negatively correlated with their attitude towards science. Cannon and Simpson (1985) also found positive but significant correlation between students' attitudes towards science and their science achievement. On this matter, students' attitudes towards science was measured by attitudes towards science subscale from the 'Simpson-Troost Attitude Questionnaire' (Simpson & Troost, 1982) whereas a summative content written test was used to measure students' science achievement. In this study, students' attitudes towards science were positively correlated to students' science process skills (r = .183), locus of control (r = .289), science achievement (r = .129) and not significantly correlated to students' logical thinking abilities.

Tobin and Capie (1982) found that there was significant correlation between formal reasoning abilities and science process skills. Their findings also revealed that formal reasoning abilities were the best predictors to students' science process skills. Similarly, in this study logical thinking abilities were positively correlated to students' science process skills (r = .355).

Padilla *et al*. (1984) found that the inclusion of specific integrated science process skills activities in the science curriculum enhanced students' science achievement. Likewise, in this study science process skills were positively and statistically significantly correlated to students' science achievement (r = .582).

Research done by Germann (1988) showed that there was low but significant correlation between students' general attitude and their science process skills which were measured by the 'Test of Integrated Process Skills'(TIPS) (Dillashaw & Okey, 1980) and the 'Processes of Biological Inquiry Test' (PBIT) (Germann, 1985). Similarly, this study also documented a low but statistically significant correlation between students' attitude towards science and their science process skills.

Roadrangka (1995) revealed that there was moderate correlation among formal reasoning abilities and students' achievement in biology, physics, and chemistry. On this matter, students at formal operational stage scored significantly higher in biology, physics, and chemistry test compared to students at concrete operational stage whereas those at formal operational stage scored significantly higher in physics and chemistry as compared to those at transitional stage.

Meta analysis done by Kalechstein and Nowicki (1997) showed that there was correlation between students' locus of control and their academic achievement with students' age as moderator variable. More significant correlation was found to exist among secondary school students.

The Influence of Logical Thinking Abilities, Attitude towards Science, and Locus Of Control on Students' Science Process Skills

The second null hypothesis was tested by using the stepwise multiple regression analysis technique. Results (see Table 3) showed that logical thinking abilities and attitudes towards science significantly contributed to students' science process skills ($F(2, 413) = 74.022$, $p < .0005$). Based on the Beta value, logical thinking abilities ($\beta = .470$, $t(416) = 11.137$, $p < .0005$) contributed more to the variance in students' science process skills compared to attitude toward science ($\beta = .215$, $t(416) = 5.095$, $p < .0005$). The value of coefficient of determination, R^2 (= .264) revealed that logical thinking abilities and attitudes towards science accounted for 26.4% of the variance in students' science process skills. Logical thinking abilities contributed 21.8% followed by attitudes towards science with 4.6%. Thus, this finding had successfully rejected the second null hypothesis.

Table 3
Multiple Regression Results for Logical Thinking Abilities, Attitude toward Science, and Locus of Control on Science Process Skills (N = 416)

Predictor variables	*B*	*SE*	β	ΔR^2	*t*	*p*
Constant	22.744	2.943	-	-	7.728*	< .0005
Logic	1.867	.168	.470	.218	11.137*	< .0005
Attitude	.322	.063	.215	.046	5.095*	< .0005
Locus	-	-	.055	-	1.246	.214

*$p < .05$; Process = 22.744 + 1.867 Logic + .322 Attitude
Multiple-R = .514
$R^2 = .264$; Adjusted $R^2 = .260$; SEE = 7.2385
F (2,413) = 74.022; $p < .0005$

Logical thinking abilities were found to be better predictors for science process skills as compared to attitudes towards science. Positive attitudes towards science alone did not guarantee better achievement in science process skills. This finding was further supported by stronger positive correlation between students' science process skills and logical thinking abilities compared to their attitudes towards science. Previous researches (e.g., Germann, 1994; Padilla *et al*., 1984; Tobin & Capie, 1980, 1982) also revealed that formal reasoning abilities were the best predictors for students' achievements in science process skills. For instance, Tobin and Capie (1980) reported that students at formal operational stage scored better in science process skills and approximately 30% of the variance in science process skills was contributed by students' formal reasoning abilities.

The Influence of Science Process Skills, Logical Thinking Abilities, Attitudes towards Science, and Locus of Control on Students' Science Achievements

The third null hypothesis was also tested by using stepwise multiple regression analysis technique. Results (see Table 4) showed that science process skills and logical thinking abilities significantly contributed to students' science achievement ($F(2, 397) = 105.625$, $p < .0005$). Based on the R^2 value, these two predictor variables explained 34.7% of the variance in students' science achievement. In this matter, science process skills ($R^2 = 33.9\%$, $\beta = .534$, $t(400) = 11.609$, $p < .0005$) contributed more to students' science achievement compared to logical thinking abilities ($R^2 = 0.8\%$, $\beta = .103$, $t(400) = 2.235$, $p = .026$). Thus, the third null hypothesis was successfully rejected. The contribution of attitudes towards science and locus of control on students' science achievement were not significant since the correlation between attitudes towards science and locus of control with science achievement were low as well.

Table 4
Multiple Regression Results for Science Process Skills, Logical Thinking Abilities, Attitude toward Science, and Locus of Control on Science Achievement (N = 400)

Predictor variables	B	SE	β	ΔR^2	t	p
Constant	2.245	1.162	-	-	1.932	.054
Process	.340	.029	.534	.339	11.609*	< .0005
Logic	.258	.115	.103	.008	2.235*	.026
Locus	-	-	.067	-	1.636	.103
Attitude	-	-	.036	-	.872	.384

*$p < .05$; Science = 2.245 + .340 Process + .258 Logic
Multiple $R = .589$
$R^2 = .347$; Adjusted $R^2 = .344$; SEE = 4.3163
F (2, 397) = 105.625; $p < .0005$

The findings showed that science process skill was a better predictor for science achievement compared to logical thinking abilities. Better achievement in science process skills will enhance better science achievement as compared to logical thinking abilities. This finding was further supported by stronger positive correlation between students' science achievement and their science process skills compared to logical thinking abilities (see Table 1). This finding was coherent with previous research that stressed that science process skills were the vehicles for generating science content knowledge and ways for formulating science concepts (Funk, Okey, Fiel, Jaus, & Sprague, 1979). Basic science process skills seems to prepare the basic intellect for problem solving whereas integrated science process skills were the tools used for problem solving (Burns, Okey, & Wise, 1985).

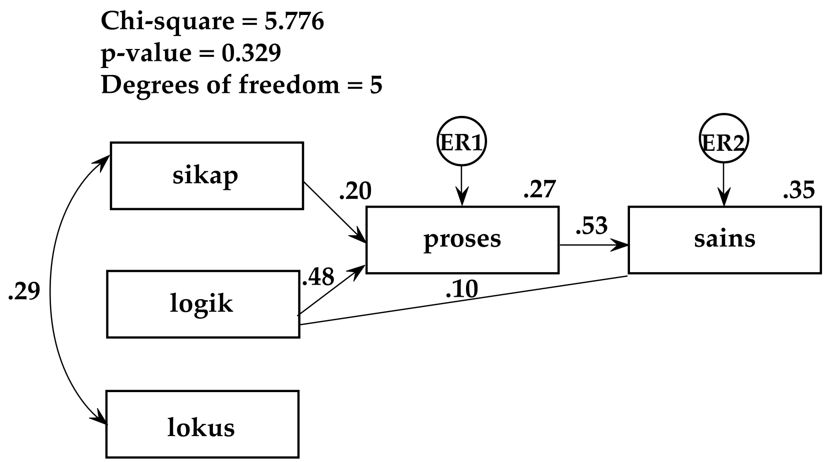
AMOS 4 Path Analysis Results

The fourth null hypothesis was tested by using path analysis technique. The model fit of the structural model generated in this study was determined prior to further analysis about the direct, indirect, and total effects among the exogenous and endogenous variables. Goodness-of-fit results showed that the structural model was fit and matched the correlation matrices of sample data collected in this study. In details, the likelihood-ratio Chi-square statistic analysis (χ^2 = 5.776, p = .329, df = 5) revealed that the difference between the implied covariance (IC) and sample covariance (SC) is very small. The p value (exceeded .05) showed that there was no significant difference between IC and SC (fail to reject H_o: IC = SC). The positive degrees of freedom value proved that the structural model was over-identified with some generalisability. On the other hand, the goodness-of-fit indices also fulfilled the criterion recommended by Bentler (1990), Bentler & Bonnett (1980), and Hair *et al*. (1998) hence further strengthen the evidence that the structural model generated in this study was fit based on the sample data: GFI (.994) (> .95); RMSR (.035) (< .08); RMSEA (.020) (< .08); AGFI (.983) (> .90); TLI (.995) (> .90), and NFI (.983) (> .90). Furthermore, indices such as RFI (.965), IFI (.998), and CFI (.998) showed value close to one whereas normed chi-square (χ^2 / df = 1.155) was in the range of 1 to 2.

Further analysis aimed at identifying significant paths in the structural model generated in this study was conducted. The results showed that four out of seven hypothesised paths in the model were significant at a specified significance level, $p < .05$ i.e. paths from Process → Science ($\beta = .535$, $p < .05$; $CR > 1.96$); Logic → Process ($\gamma = .477$, $p < .05$; $CR > 1.96$), Attitude → Process ($\gamma = .199$, $p < .05$; $CR > 1.96$), and Logic → Science ($\gamma = .103$, $p < .05$; $CR > 1.96$). Thus, this finding had rejected the stated null hypothesis with 95% confidence level. Besides, the path from Attitude <—> Locus ($r = .289$, $p < .05$; $CR > 1.96$) was also found to be significant at $p < .05$.

Path Diagram

The path diagram for the influence of science process skills, logical thinking abilities, attitude toward science, and locus of control on science achievement (see Figure 1) portrayed that attitude toward science (Attitude) ($\gamma = .199$, $p < .05$) and logical thinking abilities (Logic) ($\gamma = .477$, $p < .05$) directly contributed 26.7% of the variance in science process skills (Process) for all respondents. On the other hand, attitude toward science (Attitude), logical thinking abilities (Logic) ($\gamma = .103$, $p < .05$), and science process skills (Process) ($\beta = .535$, $p < .05$) directly and indirectly contributed 34.9% of the variance in students' science achievement (Science). However, locus of control (Locus) only showed positive correlation ($r = .289$, $p < .05$) with attitude toward science (Attitude) among the respondents.



(Legend: sikap = attitude; logik = logic; lokus = locus; proses = process; sains = science)

Figure 1. Path diagram for the influence of science process skills, logical thinking abilities, attitude toward science, and locus of control on science achievement.

Limitation of the Study

In this study, students' science process skills, logical thinking abilities, attitudes towards science, locus of control, and science achievement were measured by using tests and questionnaires. All the data collected from samples were analysed quantitatively since the ultimate goal of this research was to propose a direct and indirect effects structural model to predict students' science achievement based on science process skills, logical thinking abilities, attitudes towards science, and locus of control. One of the limitations of this study was the relatively low reliability scores of instruments used. As indicated in Table 1, the reliability scores ranged from 0.52 (Group Assessment of Logical Thinking Abilities or GALT) to 0.72

(Integrated Science Process Skills Test or ISPST). Even though these scores were deemed acceptable as these were higher than the threeshold of 0.50 set by Nunnally (1978), however the improvement on instruments may enhance the instruments reliability for the future research.

Conclusion

Stepwise multiple regression analysis found that logical thinking abilities and attitudes towards science significantly contributed to 26.4% of the variance in science process skills. Science process skills and logical thinking abilities also accounted for 34.7% of the variance in science achievement. The results of path analysis revealed that logical thinking abilities and attitudes towards science had direct effects on science process skills; science process skills and logical thinking abilities had direct effects on science achievement while logical thinking abilities and attitudes towards science also had indirect effects through science process skills on science achievement. The structural model generated in this study was fit and found to fulfill the goodness-of-fit requirements recommended in absolute fit measures, incremental fit measures, and parsimonious fit measures.

These findings showed that positive attitude towards science and higher logical thinking abilities will ensure better science process skills and hence better science achievement. Thus, those who are involved in the planning and implementation of science curriculum at primary and secondary level need to consider effective intervention programmes to increase logical thinking abilities and nurture positive attitude towards science in an effort to improve students' science process skills and science achievement especially in the Interior Division of Sabah, Malaysia.

References

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin*, *107*, 238-246.

Bentler, P.M., & Bonnett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin*, *88*, 588-606.

Burns, J. C., Okey, J.R., & Wise, K. C. (1985). Development of an Integrated Process Skill test: TIPS II. *Journal of Research in Science Teaching, 22*(2), 169-177.

Cannon, R. K., & Simpson, R. D. (1985). Relationships among attitude, motivation, and achievement of ability grouped, seventh-grade, life science students. *Science Education*, *69*(2), 121-138.

Crandall, V. C., & Crandall, B. W. (1983). Maternal and childhood behaviors antecedents of internal-external control perceptions in young childhood. In H. M. Lefcourt (Ed.), *Research with the locus of control construct. Volume 2: Developments and social problems*, pp. 53 - 103. San Diego, CA: Academic Press.

Crandall, V. C., Katkovsky, W., & Crandall, V.J. (1965). Children's beliefs in their own control of reinforcements in intellectual-academic achievement situations. *Child Development*, *36*, 91-109.

Dillashaw, F. G., & Okey, J. R. (1980). Test of the integrated science process skills for secondary science students. *Science Education*, *64*(5), 601-608.

Funk, H. J., Okey, J. R., Fiel, R. L., Jaus, H. H., & Sprague, C. S. (1979). *Learning science process skills*. Debuque, Iowa: Kendall / Hunt Publishing Co.

Germann, P. J. (1985). *The Processes of Biological Investigation Test: Development and validation*. Paper presented at the meeting of the New England Educational Research Organization, Rockport, ME.

Germann, P. J. (1988). Development of the attitude toward science in school assessment and its use to investigate the relationship between science achievement and attitude toward science in school. *Journal of Research in Science Teaching*, *25*(8), 689-703.

Germann, P. J. (1994). Testing a model of science process skills acquisition: An interaction with parents' education, preferred language, gender, science attitude, cognitive development, academic ability, and biology knowledge. *Journal of Research in Science Teaching*, *31*(7), 749-783.

Hair, J. F., Anderson, R. E., Tatham, R. L., & Black, W. C. (1998). *Multivariate data analysis*, 5th Ed. New Jersey: Prentice Hall Inc.

Haladyna, T., Olsen, R., & Shaughnessy, J. (1982). Relations of student, teacher, and learning environment variables to attitudes toward science. *Science Education*, *66*(5), 671-687.

Haladyna, T. (1982). Relations of student, teacher, and learning environment variables to attitudes toward social studies. *Journal of Social Studies Research*, *6(2)*, 36-44.

Haladyna, T., & Shaugnessy, J. (1982). Correlates of attitudes toward social studies. *Theory and Research in Social Education*, *10*(1), 1-26.

Kalechstein, A.D., & Nowicki, S. Jr. (1997). A meta-analysis of the relationship between control expectancies and academic achievement: An 11-year follow up to Findley and Cooper. *Genetics, Social & General Psychology Monographs*, *123*(1), 29-56.

Krejecie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement*, *30*(3), 607-610.

Miles, J., & Shevlin, M. (2001). *Applying regression and correlation. A guide for students and researchers*. London: Sage Publications.

Ministry of Education (2000). *Third International Science and Mathematics Study - Repeat* (2000). Kuala Lumpur: Ministry of Education, Malaysia.

Nunnally, J. (1978). *Psychometric theory* (2nd ed.). New York: McGraw Hill.

Padilla, M. J., Cronin, L., & Twiest, M. (1985). *The development and validation of a test of basic process skills.* Paper presented at the annual meeting of The National Association for Research in Science Teaching, French Lick, Indiana.

Padilla, M. J., Okey, J. R., & Garrard, K. (1984). The effects of instruction on integrated science process skill achievement. *Journal of Research in Science Teaching*, *21*(3), 277-287.

Roadrangka, V. (1995). *Formal operational reasoning ability, cognitive style and achievement in Biology, Physics, and Chemistry concepts of Form 4 students in Penang, Malaysia*. SEAMEO Regional Centre for Education in Science and Mathematics, Penang.

Roadrangka, V., Yeany, R. H., & Padilla, M .J. (1983). *The construction of a Group Assessment of Logical Thinking (GALT).* Paper presented at the 56th annual meeting of the National Association for Research in Science Teaching. Dallas, Texas, April, 5-8.

Shaughnessy, J., Haladyna, T., & Shaughnessy, J. M. (1981). *Relation of student, teacher, and learning environment variables to attitudes toward math*. Paper presented at the annual meeting of the American Educational Research Association, Los Angeles.

Simpson, R. D., & Troost, K. M. (1982). Influences on commitment to and learning of science among adolescent students. *Science Education*, *66*(5), 763-781.

Tobin, K. G., & Capie, W. (1980). Teaching process skills in the middle school. *School Science and Mathematics*, *80*(7), 590-600.

Tobin, K. G., & Capie, W. (1981). The development and validation of a Group Test of Logical Thinking. *Educational and Psychological Measurement*, *41*, 413-423.

Tobin, K. G., & Capie, W. (1982). Relationships between formal reasoning ability, locus of control, academic engagement and integrated process skill achievement. *Journal of Research in Science Teaching*, *19*(2), 113-121.

Wan Mohd. Zahid Mohd. Nordin (1993). *Wawasan pendidikan agenda pengisian*. Kuala Lumpur: Nurin Enterprise.