LEVELS OF TEACHER TRAINEES' ACQUISITION OF INTEGRATED SCIENCE PROCESS SKILLS IN AUTHENTIC CONTEXTS

[1]Nik Azmah Nik Yusuff, [2]Ong Eng Tek, [3]Norazilawati Abdullah, [4]Rosnidar Mansor
Sultan Idris Education University, Malaysia

Abstract

The purpose of the study is to identify the levels of teacher trainees' acquisition of integrated science process skills (ISPS) as a whole, and the level acquired for each of the five subskills in ISPS, namely identifying variables, operationally defining, identifying testable hypothesis, data and graph interpretation, and experimental design. It also establishes the differences in ISPS acquisition by English proficiencies. Additionally it also surveys the teacher trainees' evaluation of the effectiveness of the laboratory manual they used to aid the teaching and learning of science process skills. Using a causal comparative design, TIPS-II of Burns, Okey, and Wise's Test of Integrated Process Skills II was administered to a total of 142 science teacher trainees from Sultan Idris Education University, Malaysia. The data collected was analysed descriptively in terms of percentage mean score for fair comparison, and inferentially using one-way ANOVA. The results indicated that the achievement level of the overall ISPS was 86.93%, and the achievement level of each subskill in ISPS was 77.70% to 93.43%. The one-way ANOVA indicated that the difference in percentage correct acquired by the teacher trainees was significant according to their proficiencies in English language. Also, the teacher trainees evaluated the laboratory manual as an effective aid in helping them comprehending science process skills.

Keywords *science process skills, acquisition, laboratory manual*

Abstrak

Tujuan kajian ini ialah untuk mengenal pasti tahap penguasaan kemahiran proses sains bersepadu (KPSB) guru pelatih secara keseluruhan, dan tahap penguasaan setiap satu daripada lima sub kemahiran dalam KPSB, iaitu mengenal pasti pemboleh ubah, mendefinisi secara operasi, mengenal pasti hipotesis boleh uji, menginterpretasi data dan graf, dan mereka bentuk eksperimen. Juga bertujuan untuk mengenal pasti perbezaan pada tahap penguasaan KPSB berdasarkan penguasaan bahasa Inggeris dan major pengajian mereka. Tinjauan ke atas guru pelatih turut dilakukan untuk mereka menilai keberkesanan manual makmal yang telah mereka gunakan untuk membantu pengajaran dan pembelajaran kemahiran proses sains. Dengan menggunakan reka bentuk kajian *causal-comparative,* TIPS-II *Test of Integrated Process Skills II* (Burns, Okey, & Wise, 1985) ditadbirkan kepada 142 guru pelatih sains di Universiti Pendidikan Sultan Idris. Data yang dikutip dianalisiskan secara deskriptif dari segi peratusan skor min untuk perbandingan yang saksama dan secara inferential dengan menggunakan ANOVA satu-hala. Dapatan kajian menunjukkan tahap penguasaan KPSB secara keseluruhan ialah 86.93%, dan tahap penguasaan setiap sub kemahiran ialah daripada 77.70% hingga 93.43%. Dapatan ANOVA satu-hala menunjukkan perbezaan peratusan betul yang dicapai oleh guru pelatih adalah berbeza secara signifikan dengan tahap penguasaan bahasa Inggeris mereka. Juga guru pelatih telah menilai manual makmal yang mereka gunakan sebagai berkesan dalam membantu mereka memahami kemahiran proses sains.

Kata kunci *Kemahiran proses sains, penguasaan, manual makmal*

INTRODUCTION

Teaching science education in schools is a challenge to every science teacher. This is because it is a common goal to make science learning better resemble science practice. According to Edelson (1998) the key features of scientific practice fall into three categories of attitudes, tools and techniques, and social interaction. Scientific practice is characterized by the attitudes of uncertainty and commitment. Tools and techniques include a set of tools and techniques that have been developed and refined over the history of the field. Whereas social interaction is the sharing of results, concerns and questions among a community of scientists. The interaction has the same mix of cooperation and competition, agreement and argumentation that accompanies all human social activity. Also, Edelson (1998) states that any complete adaptation of scientific practice will need to address three primary issues, curriculum structure; teacher preparation; and learner. The challenge in addressing these issues is achieving authenticity within the practical constraints of the classroom environment. Current, fixed curricula present a significant obstacle to the use of authentic scientific practice in the classroom, because of the flexibility in time and topic required for students to wrestle with uncertainty and pursue issues to which they are personally committed. Traditional training for teachers has not prepared them for new roles in which they must engage students in uncertain science, help them to formulate and refine research question, identify resources and tools that will allow them to expand their understanding and foster authentic scientific debate.

According to Padilla (1990), one of the most important and pervasive goals of schooling is to teach students to think. Science contributes its unique skills, with its emphasis on hypothesizing, manipulating the physical world and reasoning from data. The scientific method, scientific thinking and critical thinking have been terms used at various times to describe these science skills. Today the term "science process skills" is commonly used. Popularized by the curriculum project, Science – A Process Approach (SAPA). These skills are defined as a set of broadly transferable abilities, appropriate to many science disciplines and reflective of the behaviour of scientists. SAPA grouped process skills into two types basic and integrated. The basic (simpler) process skills provide a foundation for learning the integrated (more complex) skills.

The five integrated skills discussed here are controlling variables (being able to identify variables that can affect an experimental outcome, keeping most constant while manipulating only the independent variable. Example: Realizing through past experiences that amount of light and water need to be controlled when testing to see how the addition of organic matter affects the growth of beans), defining operationally (stating how to measure a variable in an experiment. Example: Stating that bean growth will be measured in centimeters per week), formulating hypothesis (stating the expected outcome of an experiment. Example: The greater the amount of organic matter added to the soil, the greater the bean growth), interpreting data (organizing data and drawing conclusions from it. Example: Recording data from the experiment on bean growth in a data table and forming a conclusion which relates trends in the data to variables), and experimenting (being able to conduct an experiment, including asking an appropriate questions, stating a hypothesis, identifying and controlling variables, operationally defining those variables, designing a "fair" experiment, conducting the experiment, and interpreting the results of the experiment. Example: The entire process of conducting the experiment on the effect of organic matter on the growth of bean plants).

Teaching the process of science means going beyond the content to help students understand how we know what we know and giving them the tools they need to think scientifically (Egger, 2009). Most importantly, it involves making explicit references to the process of science (Lederman, 2007, as cited in Egger, 2009). And allowing students time to reflect on how they have participated in the process (Schwartz et al., 2004, as cited in Egger, 2009).

Padilla (1990) stated that Wright (1981) found that students can be taught to formulate hypothesis and that this ability is retained over time. Padilla, Okey and Garrard (1984) as cited in Padilla, (1990), have systematically integrated experimenting lessons into a middle school science curriculum. One group of students was taught a two week introductory unit on experimenting which focused on manipulative activities. A second group was taught the experimenting unit, but also experienced one additional process skill activity per week for a period of fourteen weeks. Those having the extended treatment outscored those experiencing the two week unit. These results indicate that the more complex process skills cannot be learnt via a two week unit in which science content is typically taught. Rather, experimenting abilities need to be practised over a period of time.

Experimenting abilities is said to be closely related to the formal thinking abilities described by Piaget. According to Padilla (1990) teachers cannot expect mastery of experimenting skills after only a few practice sessions. Instead students need multiple opportunities to work with these skills in different content areas and contexts. Teachers need to be patient with those having difficulties, since there is a need to have developed formal thinking patterns to successfully "experiment". This is in line with the result of a study by Brotherton and Preece (1996) on the effects of teaching science with a special emphasis on process skills. Year 7, 8 and 9 classes took part in the 28-week intervention proved to be particularly effective in promoting science process skills and in raising the Piagetian development level in year 8 males. In delayed post-tests nine or ten weeks after the intervention, the positive effects on cognitive ability were still present. The results are interpreted in terms of "readiness" associated with a spurt in brain development.

Regarding teacher education, the Massachusetts State Department of Education in a report on science instruction in their elementary schools claims that their teachers lack basic science skills. They suggest that teacher education students should be involved in considerable hands-on science to develop the appropriate skills (1987, as cited in Foulds & Rowe, 1996).

It has been established for a long time that science process skills can be successfully taught to teacher education students. Several studies have indicated that short self-instructional courses in simple science processes significantly increase students' ability to use science processes (Jaus, 1975; Campbell & Oley, 1977, as cited in Foulds & Rowe, 1996).

Similarly, ineffective delivery of science teaching in Malaysian schools weighs heavily on the science teachers' shoulders. In this 21st century, when it is widely accepted that science teaching and learning better resemble science practice, school students are expected to master, and tested for their proficiency on science process skills besides the content of science. Thus far, the level of acquisition of science process skills of Malaysian secondary students, particularly the second (14 to 15 years olds) and the fourth (16 to 17 years olds) formers that have been tested using the Test of Integrated Process Skills II (TIPS II) did not reach the minimum level of achievement of 67%. The low achievement of less than 40% is generally found amongst the school students probably indicates that during science teaching and learning less emphasis is given by their science teachers on science process skills.

On the other hand, it is also doubtful whether their science teachers themselves master the subject of science process skills, because they may not have received special training on understanding and teaching science process skills during their study years in universities or colleges prior to becoming science teachers. For example, a study done by Yeam Koon Peng (2007) on science graduates going through a compulsory education professional course to becoming science teachers named Kursus Perguruan Lepasan Ijazah, (this is a one-year course to qualify them as teachers) found that the would be science teachers only achieved 77.6% for their integrated science process skills test.

Identifying the level of acquisition of science process skills of the science teacher trainees in universities is important, but the informative data is not by itself meaningful to educationist, unless action is taken to rectify any weaknesses to be found at university level or college level so that the institutions indeed prepare the future science teachers of quality to cope with the science teaching reforms. This research is to identify the level of teacher trainees' acquisition of integrated science process skills as a whole, and the level acquired for each of the five subskills in ISPS, namely identifying variables, identifying testable hypothesis, operationally defining, data and graph interpretation, and experimental design. Additionally, it also establishes the differences in ISPS acquisition by English proficiencies. In Malaysia, English language is used as a medium to teach science and mathematics in Malaysian universities since 2003. Also this research is to identify the effectiveness of the laboratory manual used as an effective aid in helping them comprehending science process skills.

METHOD

Test of Integrated Process Skills II (TIPS II) of Burns, Okey, and Wise's (1985) was used. The 36- item objective test could be completed in about 35 minutes. TIPS II was chosen because the items were context-friendly for use by the teacher trainees. Further more, during the development of the test, its validity and reliability was verified in the Journal of Research in Science Teaching (Burns, Okey, & Wise, 1985).

Response to a set of questionnaires built by the researcher on perception of the teacher trainees were also collected in order to get their opinions on how effective was the laboratory manual in helping them understand each subskill of the science process skills and the process skills as a whole.

A hundred and fourty two science teacher trainees from Sultan Idris Education University became the participants for this research. They were then in their third year of study in the university. They were majoring in either biology, physics or chemistry. They were grouped randomly into four groups. In a course they have undertaken called Strategies in Teaching and Learning Science, they were taught the same theory of basic science process skills on one certain day of the week for two hours. The following week, two hours were taken on another day to teach integrated science process skills. They also had to undergo practical activities for three hours in each session, once a week for four weeks, using the same laboratory manual based on science process skills.

After the teaching and learning of science process skills in theory and through practical activities, the teacher trainees sat for the TIPS II, and their marks were analysed. Later they were also asked to complete questionnaires in order to find out if the laboratory manual that they had used in the laboratory activities was effective as an educational aid to help them comprehend each subskill of the science process as well as science process as a whole. The acquired data was analysed using Statistical Package for Social Science (SPSS) 17.0. One-way analysis of variance (ANOVA), and Pearson Correlation analysis were used.

RESULTS

The participants comprised of only 28 males but 114 females who took up to 80.3% of the participants. Similarly the majority of intakes were from matriculation which took up 85.9 % of the participants. School leavers who excelled in their studies and did well in the Malaysian Certificate of Education joined matriculation colleges prior to university entry. Out of 142 teacher trainees, 35 (24.6%) majored in physics, 51 (35.9%) majored in chemistry and 56 (39.4%) majored in biology. Their Malaysian University English Test (MUET) is shown in Table 1 where 70.4% achieved band 3, 18.3% achieved band 4, and 16 of the teacher trainees (11.3%) only achieved band 2.

Table 1 *Teacher trainees' Malaysian University English Test (MUET) results.*

		Frequency	Percent
MUET Band	2	16	11.3
	3	100	70.4
	4	26	18.3
	Total	142	100.0

Integrated Science Process Skills (ISPS) as A Whole and Each of the Five Subskills

Table 2 shows the maximum score (i.e. the number of items in ISPS test), mean score, mean percentage and standard deviation of the acquired ISPS of the participants by subskills as well as overall ISPS. The mean percentage acquired by the teacher trainees was 86.93%, which is above 67.00% (the required minimum level set for school students) with the standard deviation of 8.24.

Table 2 *Mean score and mean percentage of acquired ISPS as a whole and its subskills*

Subskills	N	Maximum Score	Mean Score	Mean Percentage	Standard Deviation
Identifying Variables	142	12.00	11.12	92.66	1.38
Operationally Defining	142	6.00	4.92	82.04	1.10
Identifying Testable Hypothesis	142	9.00	7.32	81.30	1.17
Data and graph Interpretation	142	6.00	5.61	93.43	.68
Experimental Design	142	3.00	2.33	77.70	.68
Overall ISPS	142	36.00	31.30	86.93	8.24

Comparing between all five subskills in ISPS, the teacher trainees acquired 93.43% for data and graph interpretation, 92.66% for identifying variables, 82.04% for operationally defining, 81.30% for identifying testable hypothesis, and 77.70% for experimental design. In addition, each item in the subskills was examined to see which item that confuses or the teacher trainees fail to answer correctly.

Table 3 shows item number, frequency of correct answer, and percentage acquired by the teacher trainees. There were 12 items asked on the skills of identifying variables. Item no.3 (82.4%) and item no. 1 (87.3%) were found to be less than 90.0% acquired by the teacher trainees. The mean percentage for this subskill1 was 92.66%. Item no.3 and item no.1 were questions not directly involved with experiments normally done in the Malaysian schools laboratories.

Table 3a *Item number, frequency of correct answer, and percentage acquired by the teacher trainees (identifying variables)*

Item		f	%
1		124	87.3
3		117	82.4
13		128	90.1
14		139	97.9
15		131	92.3
18		134	94.4
19		142	100.0
20		133	93.7
30		133	93.7
31		137	96.5
32		129	90.8
36		132	93.0
12	%Sub1		92.66

Table 3b *Item number, frequency of correct answer, and percentage acquired by the teacher trainees (operationally defining)*

Item		f	%
2		112	78.9
7		103	72.5
22		117	82.4
23		103	72.5
26		131	92.3
33		133	93.7
6	%Sub2		82.04

Table 3c *Item number, frequency of correct answer, and percentage acquired by the teacher trainees(identifying testable hypothesis)*

Item	f	%
4	134	94.4
6	81	57.0
8	136	95.8
12	125	88.0
16	121	85.2
17	142	100.0
27	49	34.5
29	139	97.9
35	112	78.9
9	% Sub 3	81.30

Table 3d *Item number, frequency of correct answer, and percentage acquired by the teacher trainees (data and graph interpretation skills)*

Item		f	%
5		129	90.8
9		139	97.9
11		135	95.1
25		134	94.4
28		132	93.0
34		127	89.4
6	%Sub4		93.43

Table 3e *Item number, frequency of correct answer, and percentage acquired by the teacher trainees (experimental design)*

Item		f	%
10		137	96.5
21		87	61.3
24		107	75.4
3	%Sub5		77.70

There were 6 items on the skills of operationally defining. Item 7 and item 23 only gained 72.5% each, and item 2 gained 78.9% while item 22 gained 82.4%. The mean percentage for this subskills2 was 82.04%. Both item 26 and item 33 that they scored were questions involved in normal laboratory experiments.

For the subskills of identifying testable hypothesis, the mean percentages acquired by the teacher trainees were very varied. The lowest mean percentage was 34.5% for item no.27, followed by 57% for item no.6, and 78.9% for item no.35. Item no. 16 gained 85.2%, item no.12 gained 88.0%. Three other items gained above 90.0% and item no.17 gained 100.0%. The mean percentage for this subskills3 was 81.30%. All four items 4, 8, 17, and 29 used direct simple English and involved normal laboratory experiments suggested in Malaysian science curriculum specification.

There were 6 items on data and graph interpretation skills. All items gained above 90.0% mean percentages except for item no. 34 which gained 89.4%. Item 34 and item 5 (gained 90.8%) involved the skill to plot graphs from tables. The mean percentage for this subskills 4 was 93.43%.

And for the subskills experimental design, there were only 3 items, and results showed that the scores were also very varied, because the teacher trainees acquired only 61.3% for item no.21, and 75.4% for item no. 24, whilst item no. 10 they acquired 96.5%. Items no 10 was relatively asked in simple common English compared to Item no 24 and no 21.

Table 4 *Frequency, and percentage of percentage correct*

Percentage correct	Frequency	Percent
63.89	2	1.4
66.67	3	2.1
69.44	2	1.4
72.22	2	1.4
75.00	5	3.5
77.78	8	5.6
80.56	15	10.6
83.33	17	12.0
86.11	15	10.6
88.89	20	14.1
91.67	14	9.9
94.44	17	12.0
97.22	17	12.0
100.00	5	3.5

Table 4 shows frequency, and percentage of percentage correct that the teacher trainees achieved from the test. Seven teacher trainees acquired under 70.0%, 15 teacher trainees acquired more than 70.0% but under 80.0%, 67 teacher trainees acquired more than 80.0% but under 90.0%. Thus only 53 teacher trainees acquired above 90% who account for 37.32% of the participants.

Relationship of Overall Integrated Science Process Skills and English Proficiency

The relationship between MUET band and percentage correct was investigated using Pearson product-moment correlation coefficient. According to Cohen (1988) who suggested r = .10 to .29 as small, thus there was a small positive correlation between the two variables [r= .29, W=142, p<.0005], with high levels of MUET band was associated with higher percentage correct. Therefore if a teacher trainee's MUET grade was band 4, the percentage correct was high.

Table 5 showed result of percentage correct by MUET band acquired by the teacher trainees. After an analysis of one- way between-groups ANOVA was carried out as shown in Table 6 there was a statistically significant difference at the p<0.05 level between the means of percentage correct acquired by the teacher trainees according to their MUET bands. Post-hoc comparisons using the Tukey HSD test indicated that the mean score for MUET band 2 (M=83.51, SD=8.45) and MUET band 3 (M=86.22, SD=7.98) were significantly different from MUET band 4 (M=91.77, SD=7.31). The mean score for Muet band 2 did not differ significantly from MUET band 3.

Table 5 *Percentage correct by MUET*

MUET band	N	Mean	Std. Deviation
2	16	83.51	8.45
3	100	86.22	7.98
4	26	91.77	7.31
Total	142	86.93	8.24

Table 6 *Analysis of one- way between-groups ANOVA by MUET*

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	847.52	2	423.76	6.76	.00
Within Groups	8717.12	139	62.71		
Total	9564.64	141			

The Perceptions of Teacher Trainees on the Effectiveness of the Laboratory Manual as Teaching Aids

Table 7 showed the teacher trainees' mean scores and standard deviations in understanding the science process skills. The highest mean score (M=3.40, SD=0.60) was the teacher trainees' ability to comprehend the meaning of controlling variables, followed by the meaning of making hypothesis (M=3.39, SD=0.61). They understood the meaning of experimenting (M=3.35, SD=0.55) more than the meaning of operationally defining (M=3.17, SD=0.65).

Table 7 *Mean scores and standard deviations in understanding the science process skills*

Item	N	Minimum	Maximum	Mean	Std. Deviation
Comprehend each one of the Integrated SPS	109	2.00	4.00	3.15	.47
Comprehend the meaning of Controlling Variables	109	2.00	4.00	3.40	.60
Comprehend the meaning of Operationally defining	109	1.00	4.00	3.17	.65
Comprehend the meaning of Making hypothesis	109	2.00	4.00	3.39	.61
Comprehend the meaning of Experimenting	109	2.00	4.00	3.35	.55
The laboratory Manual used was effective in differentiating SPS	109	1.00	4.00	3.23	.57
Able to explain confidently to my future students the meaning of SPS	109	2.00	4.00	3.17	.52

Overall integrated science process skills received the mean score of 3.15, and a standard deviation of 0.47. The teacher trainees gave the item that the laboratory manual was effective in differentiating each subskills of science process skill the mean score of 3.23, and a standard deviation of 0.57. And they gave the mean score of 3.17, and a standard deviation of 0.52 to the item, being able to explain confidently to their future school students the meaning of science process skills.

DISCUSSION

The mean percentage acquired by the teacher trainees was 86.93% which is above 67% the required minimum level set for school students. And also much higher than the percentage acquired by the science graduates (77.6%) who participated in a study by Yeam Koon Peng (2007). However, since the teacher trainees will become science teachers, they are expected to acquire a perfect score. Even 90% will not be good enough. In this study, the teacher trainees experienced the teaching and learning of science process skills in formal classes. They were taught the process skills theoretically for a total of four hours and underwent a total of 12 hours practical classes. The sessions were carried out within a period of four weeks.

The subskill that they achieved the highest mean percentage was data and graph interpretation, but what is worrying is they couldn't answer well questions asked on skills to plot graphs from tables. They as teachers must not only know how to interpret available graphs, but must be skilled in plotting graphs correctly. Thus, during the intervention course, the skills to plot graphs must be included.

For the other subskills, they achieved high mean percentage only for questions involved in normal laboratory experiments done in schools as well as using direct simple English. And when questions asked were deviated from a familiar setting, many failed to recognize variables or define the operations correctly. And for the lowest mean percentage that they have achieved, the subskill, experimental design, again when questions asked were not directly involved in classroom laboratory experiments, and asked indirectly, they couldn't answer well. This could be interpreted that the teacher trainees haven't mastered what is meant by science process skills. They are unable to apply the knowledge in new situations.

However, their English proficiencies might be a factor of hindrance to getting better results. This is because the MUET band and percentage correct was significantly correlated at the 0.01 level. And those who got MUET band 4 achieved the highest percentage correct. This is of course not a surprise finding because content knowledge of any disciplines is taught through language as medium. If a teacher trainee is not proficient in English, the teaching and learning of science in English, and sitting for TIPS II in English would retard the process of understanding of the subject matter.

From the result of the study, it showed that the different subskills posed different difficulty levels to the teacher trainees. The subskill, data and graph interpretation being the highest mean percentage achieved by the teacher trainees implies that in Malaysian school system, students are trained to solve problems, because Malaysian school system is very inclined towards an exam-oriented system. Science process skills have not been taught properly because as examples, they are not trained enough on the skills of how graphs should be plotted, or how to design experiments. In other words, teachers in schools or higher institutions do not pay enough attention to process skills.

From the analysis of the questionnaires, it is noted that the highest mean score (M=3.4) was the teacher trainees' ability to comprehend identifying and controlling variables after using the laboratory manual. This was paralleled to their achievement in the TIPS II. However, they thought they could identify testable hypothesis better than operationally defining, but in the TIPS II they fared a little better for operationally defining than identifying testable hypothesis. The teacher trainees also thought that they understood the meaning of experimenting more than operationally defining. But in TIPS II they acquired the subskill of experimental design the lowest mean percentage. On the whole, the participants thought the laboratory manual was effective in helping them differentiate each one of the subskill in science process skills (M= 3.23).

CONCLUSION

Universities or teacher training institutions should design courses on science process skills for their science trainee teachers where they can be trained to acquire science process skills. Such courses must be planned well to include theory and practical classes. If however, that is not viable, a short intervention of teaching and learning the process skills is important and beneficial to the trainee teachers to equip them with the understanding of science process skills. However, the content of the laboratory manual can be improvised to add materials found to be lacking with the trainee teachers. And it is suggested that the duration of the intervention course should be lengthened. It is also recommended for future researchers in Malaysia, to use both English and local versions instruments to test participants for their science process skills competencies.

REFERENCES

Brotherton, P. N. & Preece, P. F. W. (1996). *Teaching science process skills*. Retrieved on 14 June 2010 from http://www.informaworld.com/smpp/content~db=all~content=a7469.

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.

Edelson, D. C. (1998). Realising authentic science learning through the adaptation of scientific practice. In B. J. Fraser & K.G. Tobin (Ed.) *International handbook of science education Part one*. London: Kluwer Academic Publishers.

Egger, A. E. (2009). *Teaching the process of science*. Retrieved on 7 June 2010, from http://serc.carleton.edu/sp/process_of_science/index.html.

Foulds, W. & Rowe, J. (1996). The enhancement of science process skills in primary teacher education students. *Australian Journal of Teacher Education.* 21(1), 16-23.

Padilla, M. J. (1990). *The science process skills. Research Matters…to the Science Teacher*, No. 9004, National Association for Research in Science Teaching. (ERIC Document Reproduction Service No.ED 266 961). [Also available online] Retrieved on 4 June 2010, from htpp://www.educ.sfu.ca/narstsite/publications/research/skill.htm.

Yeam Koon Peng (2007). *Pencapaian dan pelaksanaan kemahiran proses sains dalam kalangan guru pelatih*. Tesis Sarjana Sastera (M.A.) yang tidak diterbitkan, Universiti Sains Malaysia, Pulau Pinang.