Primary School Teachers' Understanding of Science Process Skills in Relation to their Teaching Qualifications and Teaching Experience

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Abstract

This study investigated the understanding of science process skills (SPS) of 329 science teachers from 52 primary schools selected by random sampling. The understanding of SPS was measured in terms of conceptual and operational aspects of SPS using an instrument called the *Science Process Skills Questionnaire* (*SPSQ*) with a Cronbach's alpha reliability of 0.88. The findings showed that the teachers' conceptual understanding of SPS was much weaker than their practical application of SPS. The teachers' understanding of SPS differed by their teaching qualifications but not so much by their teaching experience. Emphasis needs to be given to both conceptual and operational understanding of SPS during pre-service and in-service teacher education to enable science teachers to use the skills and implement inquiry-based lessons in schools.

Keywords: Science process skills; primary school science; primary science teachers.

Science process skills and teacher education

Being able to conduct scientific inquiry to address a problem of personal and social importance in and out of school is accepted as an integral part of science education in many curriculum documents (Wu and Wu 2011). The U.S. National Science Education Standards (NSES), for example, emphasizes the importance of inquiry by stating that inquiry is "at the heart of science learning" and is "the central strategy for teaching science" (NRC 1996, p. 31). NSES defines inquiry as follows:

> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations, and predictions; and communicating the results (NRC 1996, p. 23).

From this definition, doing inquiry for science learning entails building science process skills (SPS) (also known as 'processes of science', 'inquiry processes' and 'science processes') - not only because scientists use these SPS when engaged in problem solving and developing knowledge (Meador 2003; Temiz 2007), but because students need these skills as they use scientific reasoning and critical thinking to develop their understanding of science (Gillies and Nichols 2014).

Students also need to develop SPS to learn science with understanding (Hofstein and Lunetta 2004). Otherwise, students may not be able to incorporate emerging concepts into their knowledge system through testing the feasibility of possible explanatory ideas, or collecting relevant evidence to answer the questions, or interpreting the results in a scientific way. Acquisition of SPS has a great influence in developing mental processes such as higher order critical thinking and decision making as well (Koray, Koksal, Ozdemir and Presley 2007; Lee, Hairston, Thames, Lawrence and Herron 2002; Tseng, Tuan and Chin 2013). Individuals who can develop higher order mental processes will be able to think creatively and transfer this capability to other disciplines (Meador 2003). According to Kim (2007), when teachers focus on increasing students' SPS through inquiry-based teaching, their attitude towards science improves. Science educators thus have claimed that SPS are necessary for students to (1) become engaged in inquiry (Settlage and Southerland 2007), (2) improve science achievement (Brotherton and Preece 1996), and (3) achieve scientific literacy (Colvill and Pattie 2002). Realizing the importance of SPS in helping students learn science, researchers have argued that students need to acquire these skills early on, from primary school onwards (Nevin and Mustafa 2010); consequently SPS is an important component in the science curriculum in many countries. In Australia, for example, building science inquiry skills is one of the major components in the national science curriculum from primary to secondary education (ACARA, 2012).

It must be borne in mind that proficiency in SPS alone is not a measure of one's ability to be engaged in inquiry in science. As Windschitl (2008) asserted, if students learn science process skills in isolation, they do not understand the purposes and the application of these skills in real science investigations. The approach to inquiry involves a domain of knowledge (Roehrig and Luft 2004), which has the conceptual, procedural, and operational components. Evidence is increasing to support the view that the procedural part, the 'doing' of practical work, is intricately intertwined with the conceptual part with the underlying meaning of the processes (Metz 1995). Thus, SPS should be regarded "as a *coordinated set* of activities and *taught as a whole*" (Windschitl 2008, p. 19). Competency in SPS should be viewed as a means that will help students to acquire knowledge and to understand how the knowledge is obtained (Bati, Erturk and Kaptan 2010). Within this view is what Brown, Collins and Duguid (1989) refer to as authentic activities, through which learners experience and acquire both the procedural and conceptual knowledge of science.

The teaching of SPS is considered to take place in a science laboratory. Most of the investigations and practical work of science in schools only involve manipulating apparatus and following instructions (Ong, Ismail and Fong 2006). Scanlon, Morris, Di Paolo, and Cooper (2002) categorically state that many of the skills associated with experimental investigations are seldom explicitly taught. It is often assumed that students are able to acquire the skills simply through the experience of conducting the practical work in a laboratory environment (Tan 2000). This assumption will only facilitate the acquisition of the operational aspect of these skills but will not facilitate the conceptual understanding of scientific inquiry or science process skills involved in their investigation. Students may be able to make observations procedurally but may not have a clear conception of the purpose of making observations in scientific inquiry. Thus creativity and originality, which are hallmarks of scientific investigations, would also be difficult to develop with limited acquisition of the necessary conceptual understanding of scientific inquiry or science process skills (Emereole 2009). In order to be able to teach the skills effectively and meaningfully to children, the teacher should possess a strong understanding of the underlying meaning of SPS and exhibit competence in SPS both operationally and conceptually (Settlage and Southerland 2007).

To enhance the proficiency of beginning science teachers in the use of these skills, science teacher education programs in Malaysia have long included SPS in the curriculum. Pre-service science teachers are introduced to SPS and inquiry-based education in the science teaching methods courses. Recent research studies from various countries have found that teachers were competent in executing the practical component of SPS but lacked the conceptual knowledge underlying the skills (Emereole, 2009; Karsli, Sahin and Ayas 2009). Teachers were not able to describe science process skills adequately (Farsakoglu, Sahin, Karsli, Akpinar, and Ultay, 2008) and the mere use of the processes was considered more valuable by teachers than understanding the science processes to produce beneficial student outcomes (Aiello-

Nicosia, Sperendo and Valenza 1984). Such findings are concerning because they imply the teachers' inadequate understanding of SPS. Acquiring procedural skills must go hand-in-hand with understanding of underlying meaning of the skills in order to appropriately and effectively teach them to students. Besides, teachers who possess good procedural skills but limited conceptual understanding of SPS are less equipped to use inquiry teaching and learning strategies in their classrooms (Anderson 2002).

Objectives and research questions

For the purpose of this study we investigated the understanding of SPS among primary school science teachers in Kuala Lumpur, Malaysia. The understanding of SPS were divided into two components (conceptual and operational), and the main research questions were:

- RQ1: What is the level of primary school teachers' conceptual understanding of SPS?
- RQ2: What is the level of primary school teachers' operational understanding of SPS?

In investigating the level of teachers' SPS knowledge, we also considered the learning opportunities for them to build the understanding: their pre-service teacher education programs and their teaching experience. Teacher educators are aware that the years of teaching experience do not necessarily improve the mastery of teaching after a certain number of years (Hattie, 2009), and we examined how primary teachers build their understanding of SPS as their teaching experiences build up. In addition, there have been changes in ways to become a primary school teacher in recent years in Malaysia, and we explored the impact of different teacher education programs on their SPS knowledge. Thus, we set up the third research question as following:

- RQ3: What is the influence of teachers' qualifications and their teaching experience on primary school teachers' understanding of SPS?

Research Methods

Sample

The study involved 329 primary school science teachers who were randomly selected from 52 primary schools while attending several seminars and workshops organized by the Department of Education in Kuala Lumpur. Teachers were informed about the study and given the choice to respond to the survey. Their submission of the questionnaire was taken as indication of their informed consent to participate in the research. The distribution of the teachers based on their qualifications and teaching experience is summarised in Table 1.

The Certificate in Education (CertEd) program was organized by the Teacher Training Colleges. As a two-year course for high school graduates, this program was a popular way to become a primary school teacher. About 20 years ago, many teacher education programs were extended to become three-year diploma programs with the qualification of the Diploma in Education (DipEd). In recent years, more and more Teacher Training Colleges were promoted to higher education institutes, called Institutes of Teacher Education. The teacher certificate and diploma programs have been slowly phased out to have five-and-a-half year Bachelor of Education programs and one-year Postgraduate Diploma in Education programs for prospective teachers with a university degree. Teachers with a CertEd came to teaching before the DipEd and Grad DipEd courses were introduced in teacher education institutions in Malaysia. Thus, they are more experienced science teachers compared to teachers with a DipEd or a Grad DipEd. The Grad DipEd incorporates content in a particular science degree as well as courses relevant to education like learning theories, assessment methods, curricula, instructional strategies, etc. All qualifications involve completing a 'teaching practice' component for a stipulated period.

Table 1 Distribution of participating primary teachers according to teaching qualifications and teaching experience (N = 329)

Teaching qualifications	Number of years of teaching experience				Total number of teachers (%)
	1-5	6-10	11-15	16-30	
Certificate in Education (CertEd)	0	0	52	23	75 (22.8)
Diploma in Education (DipEd)	10	98	20	13	141 (42.9)
Postgraduate Diploma in Education (Grad DipEd)	68	45	0	0	113 (34.3)
Total number of teachers (%)	78 (23.7)	143 (43.5)	72 (21.9)	36 (10.9)	329 (100)

Research instrument

The instrument referred to as the *Science Process Skills Questionnaire* (*SPSQ*) was developed based on previous studies in Malaysia (Shahali & Halim, 2010) and in Botswana (Emereole, 2009). The *SPSQ* was first pilot tested by administering to 113 primary school science teachers and subsequently modified before production of the final version. The final version of the *SPSQ* is found in the Appendix.

The questionnaire (*SPSQ*) consisted of three sections: Part I involving demographic information of the teachers; Part II with five short-answer items on conceptual understanding of SPS; and Part III consisting of 25 multiple-choice items evaluated the respondents' operational understanding of SPS. In this instrument, the SPS involved five components, namely (a) making hypotheses, (b) controlling variables, (c) defining operationally, (d) interpreting data, and (e) experimenting.

For Part II on the conceptual understanding of SPS, the meaning of each construct of SPS was examined based on the guidelines from the Ministry of Education Malaysia (2003) (See Table 2). The benchmark responses from the pilot test were evaluated through joint consultation by three expert teachers and two lecturers in science education. The 'correct' and 'partially correct' definitions were indications of the acquisition of the conceptual knowledge associated with the SPS.

Table 2 Standard definitions of the five components of SPS (Ministry of Education Malaysia, 2003)

Science process skills (SPS)	Definition
Controlling Variables	Naming the fixed variables, manipulated variable and responding variable in an investigation. The manipulated variable is changed to observe its relationship with the responding variable. At the same time the fixed variables are kept constant.
Making Hypotheses	Making a general statement about the relationship between a manipulated variable and a responding variable to explain an observation or event. The statement can be tested to determine its validity.
Defining Operationally	Defining concepts by describing what must be done and what should be observed.
Interpreting Data	Giving rational explanations about an object, event and pattern derived from collected data.
Experimenting	Planning and conducting activities to test a hypothesis. These activities include collecting, analysing and interpreting data and making conclusions.

For the assessment of the teachers' operational understanding of SPS, the 25 items (5 items for each sub-construct of SPS) in Part III of the *SPSQ* were developed. As argued by Harlen (1999), the understanding of the SPS is influenced not only by the ability to use the skills but also by knowledge of and familiarity with the subject-matter with which the skills are used. Thus the questions in Part III were developed specifically based on the Malaysian primary school science curriculum. The reliabilities of constructs in Part III of the *SPSQ* are summarised in Table 3.

Table 3 Sub-constructs of SPS in Part III of *CKSPSQ*

Science Process Skills	Questions	No. of Questions	Reliability
Making hypothesis	1, 5, 10, 16, 18	5	0.71
Controlling variables	2, 3, 17, 20, 22	5	0.74
Defining operationally	4, 7, 19, 24, 25	5	0.79
Interpreting data	8, 12, 13, 15, 21	5	0.62
Designing experiments	6, 9, 11, 14, 23	5	0.61
Overall		25	0.88

Data collection and analysis

The assessment of the 329 teachers' responses in this study was carried out by two senior science teachers. For the definition of each component of the science process skills, the assessment focused on the extent to which respondents' ideas were correct and not whether the exact words were used. The two senior science teachers decided on the specifics of what would be regarded as 'incorrect', 'partially correct' or 'correct' during discussions with the first author. Correct definitions were scored 3; partially correct definitions with only certain aspects of the process were scored 2; and incorrect definitions with irrelevant expressions were scored 1. After several trials to score the responses, the inter-rater reliability (based on the Spearman rank order coefficient of correlation) was 0.81. With regard to the operational understanding of SPS, each participant's answers for Part III were recorded in a spreadsheet and the number of correct answers was computed.

Data on respondents' conceptual and operational knowledge of SPS for science teaching were analysed descriptively using means and standard deviations. Inferential analysis of two-way multivariate analysis of variance (MANOVA) was conducted to determine the effect of teaching qualifications and teaching experience on teachers' conceptual and operational knowledge of SPS.

Results

Primary school teachers' conceptual and operational knowledge of SPS

The descriptive statistics for both components of SPS are summarised in Table 4. The data suggest that teachers' conceptual knowledge of SPS, regardless of their teaching qualifications or teaching experience, was very low (M = 6.98), considering the possible score ranges from 5 to 15. On the other hand, the teachers' operational knowledge of SPS was found to be relatively higher (M = 20.70), based on a maximum score of 25 and a minimum score of 0. However, it should be noted that the instrument we adopted for this study used two different types of questions – open-ended questions about conceptual understanding in Part II and multiple-choice questions about operational understanding in Part III of the questionnaire. Typically, the scores of open-ended items are likely to be lower than those of multiple-choice items. This result shows that primary school teachers are generally aware of how to apply the

SPS for science teaching but lack the conceptual knowledge of what are the definitions of SPS components and why they are important, confirming the findings from previous studies (Emereole, 2009; Farsakoglu et al., 2008; Karsli, Sahin and Ayas 2009).

Table 4 Descriptive statistics for teachers' conceptual and operational knowledge of SPS based on their qualifications and experience (N = 329)

	Conceptual SPS		Operational SPS	
	Mean	SD	Mean	SD
Teaching qualifications				
CertEd	7.64	1.87	21.53	3.52
DipEd	6.77	1.83	19.65	4.29
Grad DipEd	6.81	2.17	21.50	4.08
Teaching experience (in years)				
1 – 5	6.78	2.15	20.50	4.69
6 – 10	6.90	2.01	20.34	4.14
11 – 15	7.28	2.01	21.17	3.75
≥ 16	7.17	1.42	21.08	4.24
Total	6.98	1.99	20.70	4.14

The teachers with a Cert Ed achieved the highest mean score for the conceptual understanding and the operational understanding of SPS (Mean = 7.74 for conceptual SPS, and Mean = 21.53 for operational SPS). Although the score difference between the groups of teachers with different qualifications was marginal, the fact that the teachers without a higher education degree or a longer formal teacher education outperformed the teachers with a higher education degree (DipEd) or postgraduate degree (Grad DipEd) is surprising and needs to be considered in relation to their teaching experience. As mentioned earlier, all primary teachers with a CertEd in this study had considerably more teaching experience (52 teachers with 11-15 years and 23 with 16-30 years), compared to the teachers with a DipEd and a Grad DipEd. They were senior teachers who entered teacher education institutions before the DipEd and Grad DipEd programs were introduced. As these non-degree holders built their teaching experience and attended compulsory professional development sessions, they appear to have actively constructed better understanding of SPS and scored higher than those higher education degree holders in education.

Considering the low scores on the conceptual understanding of SPS, we identified competent teachers as the ones who provided 'correct' or 'partially correct' answers for all items in Part II of the *SPSQ*; the number and percentage of teachers who demonstrated an acceptable level of conceptual understanding of SPS are presented in Table 5. (The teachers who provided 'correct' or 'partially correct' answers for all items in Part II of the *SPSQ* were considered as having 'good conceptual understanding of SPS'). The recent graduates with a higher education degree (DipEd or Grad DipEd) had a higher percentage of competent teachers in terms of conceptual understanding of SPS than the experienced primary school teachers with less prestigious teacher qualifications. About 13% of early career primary teachers with less than 5 years of teaching experience got correct or partially correct answers for the conceptual understanding items of *SPSQ* while only two of the most experienced teachers (with more than 16 years of teaching experience) achieved the competency score (5.6%). Similarly, 11.5% of teachers with a postgraduate diploma were categorized as competent while 8% of teachers with a teaching certificate were identified as such. Interestingly, this is the opposite of the mean score comparison for each group of teachers presented in Table 4.

Table 5 Comparisons of teachers' conceptual knowledge based on their qualifications and experience (N = 329)

	Number of teachers with good conceptual understanding of SPS (%)	Number of teachers with weaker conceptual understanding of SPS (%)
Teaching qualifications		
CertEd (N=75)	6 (8.0%)	69 (92.0%)
DipEd (N=141)	11 (7.8%)	130 (92.2%)
Grad DipEd (N=113)	13 (11.5%)	100 (88.5%)
Teaching experience (in years)		
1 – 5 (N=78)	10 (12.8%)	68 (87.2%)
6 – 10 (N=143)	13 (9.1%)	130 (90.9%)
11 – 15 (N=72)	5 (6.9%)	67 (93.1%)
≥ 16 (N=36)	2 (5.6%)	34 (94.4%)
Total number of teachers	30 (9.1%)	299 (90.9%)

Effect of teachers' qualifications and teaching experience on their conceptual and operational understanding of SPS

A two-way multivariate analysis of variance (MANOVA) was conducted to determine the relationship between teaching qualifications and teaching experience on primary teachers' conceptual and operational knowledge of SPS. A statistically significant difference was observed between teachers with different teaching qualifications [F (2,321) = 3.70, p = 0.01]. Since a significant MANOVA F-value was obtained for the collective dependant variables of conceptual and operational knowledge of SPS in regards to the teaching qualifications, univariate ANOVAs were conducted against each of the dependant variables. The univariate ANOVAs for teachers' conceptual knowledge [F (2,321) = 3.79, p = 0.02] and teachers' operational knowledge of SPS [F (2,321) = 4.31, p = 0.01] were significant with respect to teaching qualifications. These results indicated that the relationship between teachers' teaching qualifications and both conceptual and operational knowledge of SPS for science teaching was statistically significant.

A follow-up post hoc test was conducted to evaluate pairwise differences between the means (see Table 6). The results indicated that there was a statistically significant difference in the conceptual knowledge and operational knowledge of SPS between teachers with a Certificate in Education (CertEd) and a Diploma in Education (DipEd). There was also a significant difference in the conceptual knowledge between CertEd teachers and Grad DipEd teachers while a difference was observed between regular DipEd teachers and postgraduate DipEd teachers for the operational knowledge of SPS. In contrast to the relationship between different qualifications on teachers' understanding of SPS, no significant difference was observed based on their teaching experiences [F(2,231) = 0.55, p = 0.77]. In addition, there was no interaction between teaching qualifications and teaching experience: [F (2,321) = 1.22, p = 0.30].

Table 6 Post hoc test of differences between teaching qualifications on conceptual and operational knowledge of SPS

Dimensions of SPS	Comparison of teaching qualifications	Mean difference
Conceptual knowledge of SPS	(1) CertEd. – DipEd	0.87**
	(2) CertEd – Grad DipEd	0.83*
	(3) DipEd – Grad DipEd	-0.03
Operational knowledge of SPS	(1) CertEd – DipEd	1.89**
	(2) CertEd – Grad DipEd	0.03
	(3) DipEd – Grad DipEd	-1.86**

$^{**}p \leq 0.01$ $^{*}p < 0.05$

Discussion

With reference to RQ1 (What is the level of primary school science teachers' conceptual understanding of SPS?), the findings of this study have revealed that the participating primary school teachers' conceptual understanding of SPS was relatively low (M = 6.98 out of a total score of 15). However, when considering RQ2 (What is the level of primary school science teachers' operational understanding of SPS?), the teachers' operational understanding of SPS was relatively high (M = 20.71 out of a total score of 25). With respect to RQ3 (What is the influence of teachers' qualifications and their teaching experience on their understanding of SPS?), MANOVA analysis in this study has shown that there is significant difference in conceptual knowledge of SPS among teachers based on their teaching qualifications but not on their teaching experience.

These findings show that there was a discrepancy between teachers' level of conceptual understanding of SPS and their operational understanding. Most primary school science teachers were not able to describe the skills conceptually even though they were able to apply the skills in hypothetical situations (Emereole, 2009). The fact that the majority of the science teachers possessed good understanding of the operational component of SPS but lacked the conceptual understanding underlying the skills may imply that the instruction of SPS in teacher education programs has focused more on teachers' acquisition of these practical skills but not on teachers' conceptual mastery of SPS. Thus science education methods courses at the primary teacher education institutions attended by teachers involved in this study do not appear to be extremely helpful in raising the level of pre-service teachers' conceptual understanding of SPS.

As also reported by Ong, Ismail and Fong (2006), while at secondary school teachers in Malaysia would have experienced a relatively conventional/traditional science education which emphasized a 'following instructions' approach when conducting scientific investigations. This approach placed strong emphasis on scientific content and lacked focus on procedural knowledge and skills of fair testing (Ong, Ismail and Fong 2006). SPS were not used for the acquisition of scientific knowledge, but only to verify the scientific concepts taught to the students (Emereole 2009). This approach promotes the teachers' ability to use SPS operationally but without understanding of what is meant by each of these skills. Besides, emphasis on the conceptual mastery of SPS was not carried out because this mastery of skills was not considered important compared to the acquisition of facts. This view is not surprising as science education in Malaysian schools is examination-oriented, resulting in teachers focusing more on teaching to complete the content of the syllabus and to present information and facts in order to prepare students for public examinations (Rose 2004). Therefore, teachers generally do not consider the importance of scientific inquiry in facilitating acquisition of conceptual knowledge; instead, they appear to focus almost exclusively on knowledge acquisition in terms of learning the products of science and the use of this knowledge (Gyllenpalm, Wickman and Holmgren 2010).

In addition, the evaluation system in schools in Malaysia does not emphasise the testing of conceptual understanding of SPS in public examinations. Assessment of science subjects in these examinations only involves testing students' competence in performing the practical components of SPS. Therefore, science teachers do not feel the need to teach the conceptual knowledge of SPS. Thus the issue of having sufficient conceptual knowledge of SPS may not be important or necessary to science teachers. What is emphasized by teachers is the practical; not the theoretical aspect of SPS. This practice may then explain why the findings in this study indicate that the teachers' operational understanding of SPS are high but their conceptual knowledge is low because they are the products of an education system that emphasized this approach.

Even at university level, students are provided with science laboratory practical manuals that contain instructions about 'what to do' and the questions to be answered after they have completed these procedures (Emereole 2009). Scanlon et al. (2002) also state that one of the problems with a conventional laboratory teaching program is that relevant skills in experimental investigations are rarely taught explicitly. They reported that in most of the investigation activities, teachers expect students to acquire the skills through the experience of carrying out investigations in the science laboratory environment. Teachers hope that mastery of these skills could occur simply through experience in conducting the practical work (Tan 2000). Learning the conceptual aspects of SPS is not present in the teachers' discourse (Gyllenpalm, Wickman & Holmgren, 2010) because conceptual knowledge of SPS is not a prerequisite for science courses in higher education institutions where it is considered irrelevant. Hofstein and Lunetta (2004) added that what teachers know about SPS is the result of their own reading. Thus, science teachers from teacher education institutions are not equipped with sufficient conceptual knowledge and consequently are not able to help their students to understand SPS meaningfully. This finding implies that these science teachers would ignore the understanding of SPS theoretically but will emphasize the operational aspects of these skills. Prior research suggests that teachers who lack SPS or have a poor conceptual knowledge of these skills are less equipped to use inquiry teaching strategies and thus may not be emphasising these skills in their classrooms (Anderson 2002). These teachers may also not be portraying a positive attitude towards science among students in their classrooms (Downing, Filer and Chamberlain 1997) because of their poor conceptual knowledge. Thus if science teacher educators continue to ignore this conceptual aspect of SPS, they will continue to produce teachers who are ill-equipped to teach science and consequently, SPS.

A study by Ebru and Deniz (2010) reported that pre-service teacher education does not provide science teachers with sufficient skills in designing lesson plans that integrate SPS. Their study also showed that science teachers are not sufficiently exposed to the latest strategies of teaching through inquiry that could promote understanding and competency in SPS. Thus, the development and application of inquiry-based lesson plans should be incorporated in teacher education programs. The authors suggest that teacher education courses for prospective teachers and in-service teachers should encourage them to plan inquiry-based lessons and implement these, say, in micro-teaching sessions, so that their skills in applying SPS in teaching and learning may be improved. This is also supported by Oliveria (2009) who argues that approaches such as metacognition, reflection, discussion and micro-teaching have a role in providing student teachers with the necessary skills to plan and execute inquiry-based teaching and learning programs. Besides, these hands-on experiences in designing and implementing, could also changes in teachers' attitudes towards the perceived difficulties associated with teaching SPS, new ideas and a deeper understanding of approaches to teaching

SPS, a chance to see SPS teaching modelled in their classroom, and increased motivation to implement SPS with their own students (Kenny 2012).

Conclusion and implications

In conclusion, this study indicates that the science teachers who were involved in this study (regardless of their teaching qualifications and teaching experience) have low conceptual knowledge of SPS even though they have undergone relevant teacher education programs at universities or teacher training institutes. It may therefore be concluded that their relatively low conceptual knowledge of SPS is a result of the teacher education programs that equipped teachers with the operational aspects but not the conceptual aspects of SPS.

As reported in previous research, teachers who have poor conceptual knowledge of SPS are less equipped to use inquiry teaching and related learning strategies in their classrooms (Anderson 2002). If understanding of SPS is not emphasized in teacher education programs, there is a high likelihood that students will also have the wrong conceptions about these skills as previous studies show that there is a correlation between the level of understanding and mastery of SPS among teachers with the level of students' understanding and mastery of SPS (Aiello-Nicosia, Sperandeo and Valenza 1984). The practical implementation of science in schools also will continue to produce students who follow instructions and achieve high scores without an understanding of the SPS that they use in carrying out the practices of science. Besides, creativity and authenticity (originality), which are the bases of scientific investigation, would be difficult to develop in students with weak basic understanding of SPS.

This study raises serious implications for teacher education programs in Malaysia: teachers need to be provided with first-hand experience in inquiry as well as practice in translating these experiences into inquiry-oriented lessons in order to prepare their students to be successful teachers (Britner and Finson 2005). We cannot expect teachers who have poor conceptual knowledge of SPS to teach science by inquiry effectively. Thus teacher education programs should refocus their science education courses to explicitly include and address SPS during instruction. Prospective teachers should be involved in planning activities that integrate SPS in their instruction. This involvement will improve teachers' skills in designing and implementing inquiry-based teaching and learning involving SPS so that their conceptual knowledge can be improved and they will be able to effectively teach these SPS to their future students.

Implications for further research

The study could be extended to involve hands-on and minds-on involvement of teachers by involving them in the planning and conducting of some of the experiments in Part III of the *SPSQ*. In this way it could be possible to further evaluate their conceptual understanding of SPS as well as their proficiency in performing those SPS.

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Appendix

Science Process Skills Questionnaire (*SPSQ*)

This questionnaire is designed to evaluate teachers' acquisition of conceptual knowledge and competence levels in integrated science process skills.

PART 1: Demographic Information of Teachers

Tick (√) in the spaces provided

NO	ITEM	INFORMATION
1	Age	[ ] 20 – 30 [ ] 31 – 40 [ ] 41 – 50
2	Gender	[ ] Male [ ] Female
3	Race	[ ] Malay [ ] Chinese [ ] Indian [ ] Other (please state): ___________
4	Teaching Qualifications	[ ] Certificate in Education [ ] Diploma in Education [ ] Degree & Postgraduate Diploma in Education
5	Teaching Experience	[ ] 1-5 years [ ] 6-10 years [ ] 11-15 years [ ] ≥ 16 years
6	Teaching Option	First: _______________ Second: _______________

Part II: Conceptual Knowledge of SPS

Define or explain in your own words, the following terms in relation to science:

(a) Controlling variables:

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(b) Making hypotheses:

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(c) Interpreting data:

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(d) Defining Operationally:

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(e) Designing experiments:

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PART III: Science Process Skills Test

1. Ramlah wanted to investigate the factors that determined the growth of plants that she had planted. She assumed that the amounts of water and fertilizer and the size of the pot could affect the growth of her plants. She also assumed that the amount of sunlight and air would not affect the growth of the plants since all the plants received the same amount of sunlight. Which of the following hypotheses could be tested by Ramlah?

A. The lesser the number of plants in the pot, the healthier the plants will grow.
B. The more amount of sunlight received, the healthier the plants will grow.
C. The more air there is, the healthier the plants will grow.
D. The more fertilizer added, the healthier the plants will grow.

Questions 2 to 4

A group of students wanted to investigate the effect of the amount of water on the growth of plants. They took 12 rose plants of the same type and height. Six of the plants received 5ml of water while the other six received 10 ml of water every day. All the plants were placed in the open and received the same amount of sunlight. They also added two spoons of fertilizer to each set of plants every week. After three weeks, they found that the plants that received 10 ml of water grew better than the plants that received only 5 ml of water.

2. Which of the following is the manipulated variable (factor) in this investigation?

A. Amount of water
B. Height of plants
C. Number of leaves
D. Amount of sunlight

3. Which of the following is the responding variable (factor) in this investigation?

A Amount of water
B. Type of plant
C. Amount of sunlight
D. Growth of plants

4. How can the growth of the plants be measured in this investigation?

A. By measuring the amount of water added to the plants.
B. By counting the number of leaves on each plant at the end of the investigation.
C. By measuring the amount of fertilizer added to the plants.
D. By counting the number of caterpillars found on the plants' leaves.

5. A student wanted to investigate the factors that could affect the growth of mould on bread. He felt that the factors that could be tested were: (1) the surrounding temperature, and (2) the amount of water on the bread. The rate of growth of the mould will be determined by counting the number of black spots on the bread.
Which of the following statements is the hypothesis that could be tested to determine the factors that affect the rate of growth of mould on the bread?

A. The higher the surrounding temperature the lesser the amount of water in the bread.
B. The more the amount of water in the bread the lower the temperature of the bread.
C. The more the amount of water in the bread the higher the growth rate of mould.
D. The lower the surrounding temperature the lesser the amount of water in the bread.

6. Anita wanted to investigate whether or not the surrounding temperature would affect the rate of evaporation. She has two towels and two table cloths of the same size.
Which of the following is the best way to test her investigation?

A. Take two towels of the same size and thickness. Hang one of the towels in a room under a moving fan. Hang the other towel in another room without a moving fan. Measure the difference in the time taken for both towels to completely dry.
B. Hang a towel under a tree and the other towel under the hot sun. After one hour, compare the condition of the two towels.
C. Take two cloths of the same size. Hang one cloth under a moving fan and the other under the hot sun in strong wind. Compare the time taken for both cloths to completely dry.
D. Take two towels of the same size. Fold one towel into two and the other towel into four. Place both towels on a table under the hot sun. Compare the time taken for both towels to completely dry.

7. A student wanted to investigate the effect of performing different activities on the rate of breathing. He asked students to do push ups over different durations of time and then to count their rate of breathing. Three groups of students were involved in this investigation. Each group consisted of two students. The first group was asked to do push ups for 2 minutes, the second group for 4 minutes and the third group for 6 minutes.
How could the students measure their rate of their breathing in this investigation?

A. By counting the number of push ups in one minute.
B. By counting the pulse beat in one minute.
C. By counting the number of push ups done by each group.
D. By counting the number of push ups done by each student.

8. The table below shows the results of an investigation that was conducted to find out the effect of container's surface area on the volume of water left after 2 hours. All the three containers were placed under the hot sun.

Surface area of container (cm^2)	Initial volume of water (ml)	Volume of water after 2 hours (ml)
50	50	35
30	50	40
10	50	45

Which of the following statements best describes the effect of the container's surface area on the volume of water left after 2 hours?

A. The larger the container's surface area, the lesser the volume of water left after 2 hours.
B. The volume of water remains the same no matter the surface Area of the container.
C. The higher the surrounding temperature, the lesser the volume of water left after 2 hours
D. The smaller the container's surface area, the lesser the volume of water left after 2 hours.

9. A student wanted to investigate whether or not the higher the surrounding temperature, the higher the rate of melting of ice. How could she test her hypothesis?

A. Take two containers with different base area. Put two ice cubes into each container. Place the containers on a table. Measure the volume of water in each container every minute. After 30 minutes, compare the volume of water in each container.
B. Prepare two containers of the same size. Put one ice cube into one of the containers and two ice cubes into the other container. Leave both containers in a room. After 10 minutes, observe the size of the ice cubes in both containers.
C. Prepare a towel and a piece of paper of the same size. Wrap two ice cubes each with the towel and the paper. Leave them under the hot sun. After 30 minutes, un-wrap them and observe the size of the ice cubes.
D. Prepare two containers of the same size. Put two ice cubes each into both containers. Leave one container in a room and the other container under the hot sun. After 10 minutes, observe the size of the ice cubes.

10. Ahmad wanted to find out the factors that affect the brightness of a bulb in a series circuit. He built three series circuits. Each circuit has two bulbs and wires of the same length. The first circuit has one battery, the second circuit has two batteries and the third circuit has three batteries. The brightness of the bulbs in each circuit was observed and recorded in a table. Which of the following was the hypothesis tested in this investigation?

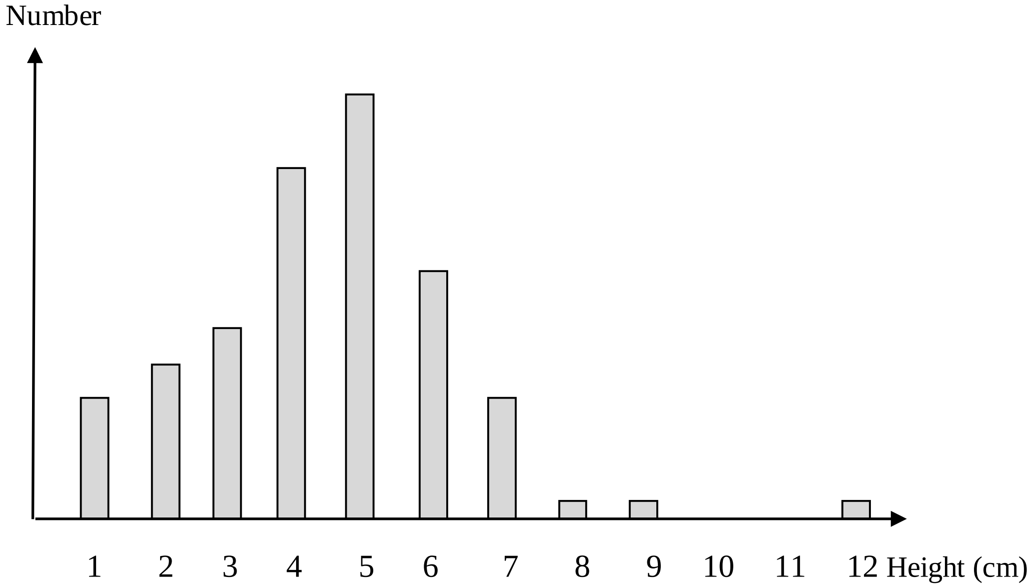
A. The brightness of the bulbs decreases when the number of bulbs increases.
B. When the number of batteries decreases the brightness of the bulb also decreases.
C. The longer the wires the dimmer the brightness of the bulb.
D. If the number of batteries increases, more electricity is produced.

11. Asma wants to investigate the factors that affect the size of a shadow. She assumed that the nearer the object from the source of light, the bigger the size of the shadow formed on the screen. Which of the following is the method to test her assumption?

A. Place a ball 5 cm away from a torch light. Then place a white cardboard in front of the ball. Move the ball and the white cardboard towards the torch light. Observe the size of the shadow formed on the white cardboard.
B. Place a ball 5 cm away from a torch light. Then place a piece of white cardboard in front of the ball. Move the ball to 4 cm away from the torch light. Observe the size of the shadow formed on the cardboard.
C. Place a ball 5 cm away from a torch light. Then place a piece of white cardboard in front of the ball. Move the ball and the torch light toward the piece of white cardboard. Observe the size of the shadow formed on the cardboard.
D. Place a ball 5 cm away from a torch light. Then place a white cardboard in front of the ball. Move the piece of white cardboard towards the torch light. Observe the size of the shadow formed on the cardboard.

Questions 12, 13 and 14 refer to the graph below.

A group of students measured the height of balsam plants in the school science garden. The results are shown in the graph below.



12. What is the height of the largest number of plants in the garden?

A	13 cm	**C**	5 cm
B	12 cm	D	1 cm

13. What is the maximum height of the plants found in the garden?

A	5 cm	C	4 cm
B	12 cm	D	10 cm

14. The group of student then wanted to find out the factors that affect the height of the balsam plants in the garden. They assumed that competition for basic needs caused the differences in the height of the plants. Which of the following is the correct method to test their assumption?

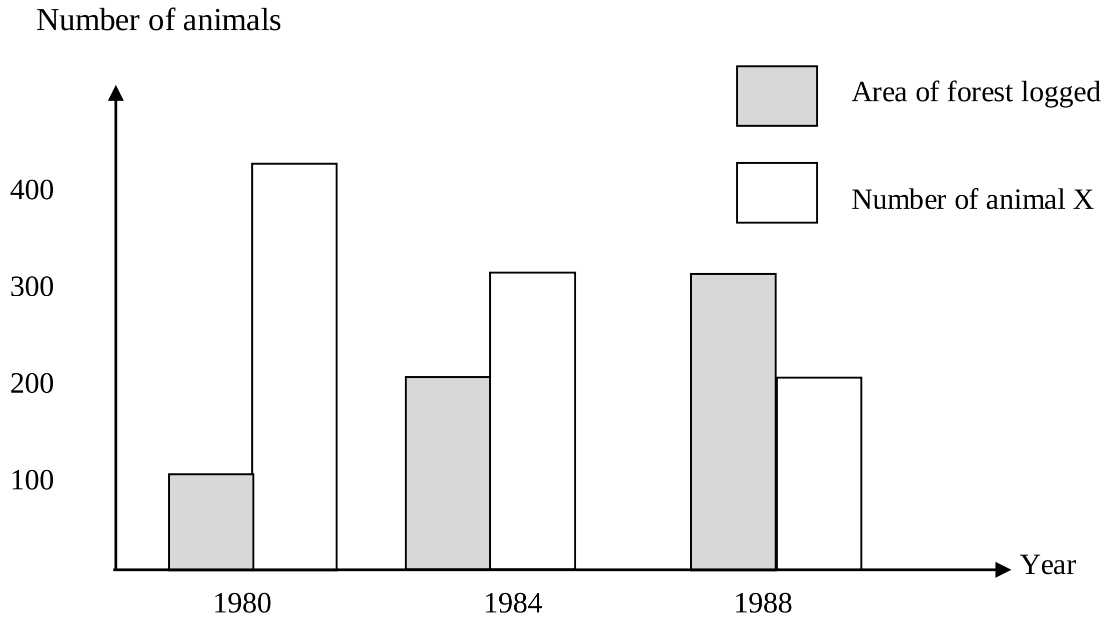
A. Take six balsam plants of the same height. Plant one plant in Pot A and the other five plants in Pot B. Water both pots with 10 ml of water every day for two weeks. Measure the height of the plants in both pots after two weeks.

B. Take three balsam plants of 5 cm height and plant them in Pot A. Then, take 3 plants of 4 cm height and plant them in Pot B. Place both pots under the hot sun and water them with the same amount of water for two weeks. Measure the height of the plants in both containers after two weeks.

C. Take six balsam plants of different heights. Plant three of the plants in Pot A and the other three in Pot B. Watere Pot A with 10 ml of water once a day and Pot B with 5 ml of water twice a day. Measure the height of the plants in both containers after two weeks.

D. Take four balsam plants of 5 cm height. Plant two of the plants in Pot A and the other two in Pot B. Watere both pots with 5 ml of water every day for two weeks. Measure the height of the plants in both containers after two weeks.

15. The graphs below show the effect of logging activity on the population of animal X.



Which of the following statements describes the relationship between the area of forest logged on the number of animal X?

A. When the logging area increases, the number of animal X increases.
B. When the logging area decreases, the number of animal X increases.
C. When the logging area decreases, the number of animal X decreases.
D. When the logging area increases, the number of animal X remains the same.

16. A farmer planted 100 tomato plants. Each plant was planted in a pot of the same size. All the pots have the same type of soil with the same amount of fertilizer. He found that some of the plants produced many tomatoes while others produced lesser tomatoes. The farmer's friend told him that the amount of water and amount of sunlight received by the plants could affect the number of tomatoes produced.
Which of the following hypotheses could be tested by the farmer?

A. The more the amount of fertilizer, the more the number of tomatoes produced.
B. The greater the distance between the plants, the more the number of tomatoes produced.
C. The more the amount of water, the more the number of tomatoes produced.
D. The bigger the size of the pot, the more the number of tomatoes produced.

17. A baker prepared two lots of dough of the same size. Both the lots of dough were made using the same amounts of flour, sugar and water. Two spoons of yeast powder were added to one lot of dough while four spoons of yeast powder were added to the other. Both lots of dough were left for an hour on the table. After one hour, he found out that the dough with four spoons of yeast was bigger than the other one.
Which of the following variables (factor) has been manipulated (changed)?

A. Amount of flour
B. Amount of yeast added
C. Size of dough after 1 hour
D. Place where the dough was left

Questions 18 & 19

Sara wanted to find out whether or not the height of a model building affects its stability. She made three building models with the same surface area but different heights. The height of the first model was 20 cm, the second model was 40 cm and the third model was 60 cm. All models were placed on the table. The table was than shaken and the stability of the models was determined.

18. Which of the following is the hypothesis that was tested by Sara in this investigation?

A. If the size of the model increases, its stability will increase.
B. If the base area of the model increases, the stability will increase.
C. If the height of the model decreases, the stability will increase.
D**.** If the weight of the model increases, the stability will increase.

19. Which of the following is the most suitable method to measure the stability of the model?

A. Measuring the base area of the model
B. Measuring the height of the model
C. Measuring the time taken for the model to topple
D. Measuring the volume of the model

20. Azhar wanted to find out the factor that causes a nail to rust. He placed a nail in a test-tube filled with boiling water and another nail in a test-tube filled with oil. After a week, she observed that the nail in the test-tube that was filled with oil did not rust but the nail in the test-tube that was filled with boiling water had rusted.
Which of the following factors (variable) affected the condition of the nails observed by him after a week?

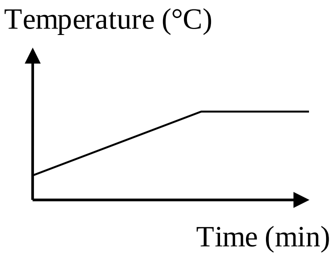
A. Volume of water
B. Type of nail
C. Size of nail
D. Presence of air

21. Azhar boiled some water in a beaker. The water temperature was measured with a thermometer. The table below shows the temperatures of water measured by him.

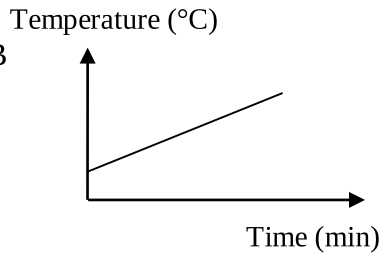
Time (min)	0	4	6	8	10	12	14
Temperature (C)	25	34	51	74	91	100	100

Which of the following graphs shows the result of his investigation?

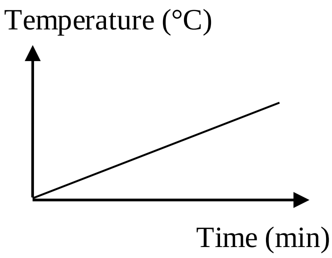
A



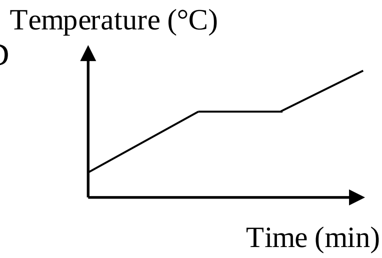
B



C



D



22. Ali, Abi and Ah Chong make a simulation to see how the distance from the sun affects the surface temperature of planets. They lighted a camp fire. Ali then sat 5 meters away from the campfire, while Abi sat 3 meters away and Ah Chong 2 meters away. In this simulation, the campfire represented the sun while the three students were the planets. Ah Chong felt hotter than Abi and Ali.
Which of the following variables (factor) was manipulated (changed) in this simulation?

A. Distance from the fire
B. Size of the fire
C. Student's body temperature
D. Gender of student

23. Azmi told Ahmad that the rougher the surfaces, the bigger the friction produced. Which of the following is NOT the way to test their hypotheses?

A. Release a toy car from a ramp at a height of 10 cm onto glass and road surfaces. Measure and compare the distance travelled by the toy car on each surface.
B. Release a toy car from a ramp at a height of 15 cm onto a road surface and a school table surface. Measure and compare the distance travelled by the toy car on each surface.
C. Release a toy car from a ramp at a height 0f 10 cm onto a table surface. Measure the distance travelled by the toy car. Then increase the height of the ramp to 20 cm and release the toy car again. Compare the difference in the distance travelled by the toy car released from each ramp.

24. Danial wanted to find out the amount of water that could be absorbed by a towel, tissue paper, paper and t-shirt. Each of these materials was soaked in four different containers filled with 100 ml of water. After a few minutes, all of these materials were taken out and the amounts of water left in the beaker were measured.
How was the amount of water absorbed by each material measured?

A. By measuring the difference between the volumes of water left in the beaker with that at the beginning.
B. By measuring the volume of water left in the beaker.
C. By measuring the duration the materials were soaked in the water.
D. By measuring the weight of the materials after being soaked in the water.

25. Cheng wanted to investigate the strength of a magnet. He used a few types of magnets with different sizes and shapes. He measured the number of paper clips that could be attracted to each magnet.
How was the strength of magnet measured in this investigation?

A. By measuring the number of paper clips attracted to each magnet.
B. By measuring the weight of the magnet.
C. By measuring the length of the magnet.
D. By measuring the hardness of the magnet.

(The answers to the 25 items are indicated in bold letters)