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PRE-SERVICE TEACHERS' FAMILIARITY, INTEREST AND CONCEPTUAL UNDERSTANDING OF SCIENCE PROCESS SKILLS

Simeon Mbewe, Vivien Mweene Chabalengula, Frackson Mumba
Southern Illinois University Carbondale, Carbondale, USA
E-mail: smbewe@siu.edu, mweene@siu.edu, frackson@siu.edu

Abstract

This study explored pre-service teachers' familiarity, interest, and conceptual understanding of science process skills. A sample comprised ninety one primary school pre-service teachers at a university in the Midwest of the USA. Participants were enrolled in two science education courses; introductory science teaching methods course and advanced science methods course. The introductory science methods course is mainly focused on developing science process skills among pre-service teachers while the advanced science methods course is focused on content and pedagogical knowledge. Data were collected through a questionnaire. Results showed that pre-service teachers had higher familiarity and interest levels in science process skills, but very poor conceptual understanding of the science process skills. Their incorrect definitions of science processes ranged from not having any idea to tautology. Moreover, most participants interchanged definitions of some science processes notably measuring and quantification; and predicting and inferring. The findings have implications for science teaching, learning and teacher education.

Key words: *conceptual understanding, familiarity, inquiry, interest, science process skills.*

Introduction

Current USA science education reforms and standards require science teachers to teach science process skills to their students (American Association for the Advancement of Science [AAAS], 1989, 1993; National Research Council [NRC], 1996). The tenets of these reforms and standards include the "processes of science" and require that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science and scientific inquiry process (NRC, 1996, p. 105). These reforms and standards have identified thirteen science process skills that are divided into two major categories known as *basic and integrated science process skills*. The basic science process skills include *observing, measuring, classifying, inferring, predicting and communicating*. The integrated science process skills include *interpreting data, identifying and controlling variables, quantifying (counting numbers), using space/time (graph) relationships, defining operationally, hypothesizing, and experimenting*.

These science process skills form an integral part of scientific inquiry (Anderson, 2002). As such, science educators propose that inquiry science is strongly facilitative of both conceptual knowledge and the acquisition of science processes (Glynn & Duit, 1995; Minstrell & van Zee, 2000). In addition to promoting deep conceptual understanding, science inquiry is often thought to increase teachers' and students' science process skills, such as data gathering, organization of information, interpreting, and communicating conclusions (Metz, 2000). As a result, extensive research has been done on inquiry science teaching and learning.

In particular, studies have examined science course content for prospective teachers (Boardman & Zembal-Saul, 2000; Dana et al. 2000; Zembal & Oliver, 1998), and teacher preparation courses and/or programs aimed at developing understanding and abilities associated with effective science teaching in school classrooms among teachers (Marion et al. 1999; Zembal-Saul et al., 1999). However, research studies rarely discuss teachers' conceptual understanding of the science process skills such as scientific problem, hypothesis, assumption, prediction, conclusion, and models. Yet, conceptual understanding is the key to the full realization of what concepts are worth and it is widely acknowledged as one of the central goals of science education (Barbosa & Alexander, 2004). The premium placed on conceptual understanding is illustrated by its prominence as an objective in the National Assessment of Educational Progress (NAEP) science assessment (O'Sullivan, Reese, & Mazzeo, 1997). Among the definitions of characteristic elements of knowing and doing science, conceptual understanding is included. Similarly, Settlage and Southerland (2007) viewed the science process skills as an integral feature of the actions of the scientific culture, although not as all there is to science. Settlage and Southerland further states that teaching with an eye toward science process skills is an appropriate entry point for beginning primary and middle school teachers. As a result, they proposed that science process skills serve as a very important way for new teachers to learn about science teaching. Therefore, teachers should possess a strong conceptual understanding of the science process skills if they have to effectively teach them in their classrooms.

Although science process skills form an integral part of inquiry teaching (Anderson, 2002; Glynn & Duit, 1995; Minstrell & van Zee, 2000) and emphasized in science education reforms (AAAs, 1993; NRC, 1996), few studies have investigated teachers' familiarity with science process skills and their conceptual understanding of science process skills. For instance, Emereole (2009) investigated conceptual knowledge of science process skills among high school pre-service science teachers in Botswana. Emereole's study found that pre-service high school science teachers did not have sufficient conceptual knowledge of science process skills. Similarly, many studies have examined teacher understanding of inquiry and have concluded that they lack a sufficient understanding of such a process (Lotter, Harwood, & Bonner, 2007).

Despite the aversion to inquiry, many studies have supported the fact that inquiry and science process skills are closely related. For example, Luft (2001) found that pre-service teachers' achievement in science process skills were significantly improved with hands-on activities. Further, Metz, (2000), along with several others, states that the science process skills are essential to doing inquiry. Teachers who are deficient in science process skill conceptual knowledge further add to the deficiencies in teaching science by inquiry.

It is evident in the literature that few studies have explored primary school pre-service teachers' conceptual understanding of science process skills. In addition, no study has explored the extent to which teachers are familiar with the science process skills, and their levels of interest in learning more about the science process skills. Yet, it is important to find out teachers' conceptual understanding of the science process skills and their interest in knowing more about science process skills. Primary school teachers need to show strong interest in science process skills and demonstrate a sound conceptual understanding of the science process skills in order to effectively create conditions for their development among students. As such, there is also need to establish teachers' levels of familiarity and interest in science processes. Therefore, this

study attempted to find out the extent to which primary school pre-service teachers were familiar with the science process skills, were interested in knowing more about the science process skills, and the extent to which they understood the science process skills.

This study was guided by three research questions: (a) To what extent are primary school pre-service teachers familiar with science process skills? (b) To what extent are primary pre-service teachers interested in knowing more about science process skills? (c) To what extent do primary pre-service teachers understand science process skills?

Methodology of Research

This study was conducted in a primary school teacher education program at a university in the Midwest of the USA. A sample comprised 91 primary school pre-service teachers who were enrolled in two science education courses: an introductory science teaching and an advanced science teaching methods courses. Sixty (60) of the participants were in the introductory science methods course and 31 participants were in the advanced science methods course. The introductory science methods course is mainly focused on developing science process skills among pre-service teachers while the advanced science methods course is focused on content and pedagogical knowledge. The average age of the participants was 24 years. None of the participants had a school teaching experience. These pre-service teachers had already taken, prior to this study, two science content courses that covered life science, earth science and physical science concepts aligned with the national and state science education standards.

Data was collected by administering questionnaire during class which lasted for about 45 minutes in each class. The completed questionnaires were collected immediately upon completion for analysis. The questionnaire was adapted from the one used by Emereole (2009). However, a component on interest was added to the questionnaire, in order to find out if the pre-service teachers were interested in learning more about the science process skills. The questionnaire had three sections. Section 1 was intended to collect general demographic information of the participants such as gender, area of certification, teaching subjects, number of science courses taken at college/university, number of science courses taken at high school, the courses done at college/university and the courses currently taken at college/university. Section 2 consisted of two parts: Table A and Table B. Table A had 13 science processes skills and each had three responses: *Term not familiar to me, Term familiar to me but I do not understand its meaning, and Term familiar to me and I understand its meaning*. Table B also had 13 science process skills and each had three responses: *Not at all interested in receiving information, Interested in receiving more information, and Very interested in receiving more information.* Section 3 also had the same 13 science process skills with space provided where participants were expected to write definition or explanation of each process skill. It was intended to determine the conceptual understanding of the science process skills by the pre-service teachers in this study. The questionnaire was validated by three science education experts at the university this study was conducted.

Data analyses involved computing reliability values for the instrument and for each construct (familiarity, interest, and conceptual understanding). The data from section 2 was analyzed using frequency variables and descriptive statistics. One way ANOVA and t-tests were used to investigate differences among sub-groups on each of the constructs of familiarity, interest and conceptual understanding. Participants' responses in section 3 of the questionnaire were scored and categorized as correct, partially correct, and incorrect. The responses were compared to the standard answers used by Emereole (2009). The correct response was assigned a value of 3, partially correct response was assigned a value of 2, and an incorrect response was assigned a value of 1. A response was considered correct if it contained all the aspects in the standard answers completely. The response was considered partially correct if it contained some of the

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aspects in the standard answer and the response was considered incorrect if it was either completely wrong when compared to the standard answer or if the question was not answered or left blank. Then the responses were analyzed and coded to identify recurring themes.

The overall reliability value for the questionnaire was 0.93. The reliability values for the constructs *familiarity, interest and conceptual understanding* were 0.79, 0.97 and 0.37, respectively. Although the reliability value for conceptual understanding is low, the overall reliability values for the instrument and for the other two constructs are high enough to indicate some internal consistency in the instrument.

Results of Research

Levels of Familiarity, Interest, and Conceptual Understanding of Science Process Skills

Table 1 shows t-test results comparing the two science methods courses; introductory science methods course and advanced science methods course. There was a significant difference between the two classes in familiarity [t (89) = -2.39, p =0.02)]. This shows that participants in the advanced science methods course expressed more familiarity with the process skills than those in the introductory science methods course. However, there were no significant differences between the two courses in interest [(t (89) = 0.40, p =0.69)] and conceptual understanding (t (89) = -0.55, p =0.59). This shows that the pre-service teachers in the two science methods courses had the same interest and conceptual understanding levels.

Table 1. The t-test results between courses for each construct.

Construct	Intro science methods course (N= 60)	Advanced science method course (N= 31)	t	df	*p*-value	Sig
	Mean (SD)	Mean (SD)				
Familiarity	34.6 (5.1)	36.8 (2.2)	-2.39	89	0.02	Significant
Interest	24.0 (7.1)	23.5 (7.8)	0.40	89	0.69	Non significant
Conceptual Understanding	19.0 (1.7)	19.3 (2.5)	-0.55	89	0.59	Non significant

Sig at p<.05

Table 2 shows One-way ANOVA to determine any differences among the three constructs familiarity, interest, and conceptual understanding in the introductory science methods course. There was a significant difference among these three constructs (F (3,231) = 89.1, *p=0.00*). In particular, there was a difference between familiarity and interest, with familiarity having a higher mean than interest. This shows that these pre-service teachers were familiar with the science processes but had lower interest. The difference between familiarity and conceptual understanding showed familiarity with higher mean than conceptual understanding. This means that these teachers were familiar with the science processes but did not have the understanding of them. The difference between interest and conceptual understanding showed that interest had a higher mean than conceptual understanding. This means that the teachers were interested in the science processes but lacked conceptual understanding of the process skills.

Table 2. One-way ANOVA in Introductory Science Methods course.

Construct	Mean (SD)	F	df	p- value	Sig.
Familiarity	*34.6* (5.1)	*89.1*	*3* *231*	*0.00*	*significant*
Interest	*24.5* (7.1)				
Conceptual Understanding	19.1 (4.1)				

Sig at p<.05

Table 3 shows that there was significant difference among the three constructs *familiarity, interest and conceptual understanding* in the advanced science methods course. For example, there was a significant difference between familiarity and interest, with familiarity showing a higher mean than interest. Again, this shows that the pre-service teachers were familiar with the science processes but did not have interest in learning more. Another difference was between familiarity and conceptual understanding, with familiarity having a higher mean than conceptual understanding. This means that the pre-service teachers were familiar with the science processes but did not have the conceptual understanding. The difference between interest and conceptual understanding showed interest with a higher mean than conceptual understanding. This means that the pre-service teachers had interest in learning more about the science processes but did not have the conceptual understanding.

Table 3. One-way ANOVA in the Advanced Science Methods course.

Construct	Mean (SD)	*F*	*df*	*p-value*	Sig.
Familiarity	*36.9* (2.2)	*30.1*	*3* *124*	*0.00*	*significant*
Interest	*23.5* (7.8)				
Conceptual understanding	19.3 (5.1)				

Sig at p<.05

Table 4 shows the percentage comparison of the introductory science methods courses and advanced science methods course levels of familiarity in science processes. Table 4 shows that in both groups a higher percentage of the participants indicated that they were familiar and understood most of the science processes. However, in both groups pre-service teachers indicated low understanding of the science processes of quantification, making operational definitions, and using space/time relations.

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Table 4. Participants' familiarity with science process skills.

Science Process skill	Not Familiar		Familiar but not Understood		Familiar & Understand	
	Introductory science methods course	Advanced science methods course	Introductory science methods course	Advanced science methods course	Introductory science methods course	Advanced science methods course
Observation	5.0	0.0	0.0	0.0	95.0	100.0
Classification	5.0	0.0	6.7	3.2	88.3	96.8
Quantification	18.3	3.2	43.3	32.3	38.3	64.5
Measurement	5.0	0.0	3.3	0.0	91.7	100.0
Inferring	6.7	0.0	21.7	12.9	71.7	87.1
Communication	5.0	0.0	6.7	0.0	88.3	100.0
Formulating hypothesis	5.0	0.0	3.3	3.2	91.7	96.8
Experimenting	5.0	3.2	0.0	0.0	95.0	96.8
Making operational definition	26.7	22.6	53.3	35.5	20.0	41.9
Interpreting data	6.7	0.0	8.3	3.2	85.0	96.8
Predicting	5.0	0.0	1.7	0.0	93.3	100.0
Controlling variables	5.0	0.0	10.0	6.5	85.0	93.5
Using space/time relations	18.3	6.5	51.7	41.9	30.0	51.6

Table 5 shows the percentage comparison of the introductory science methods course and advanced science methods course levels of interest in science processes. A higher percentage indicates that they were just interested and not very interested or not interested at all in learning about science process skills.

Table 5. Participants' interest in science process skills.

Science Process Skill	Not at all Interested		Interested		Very Interested	
	Introductory science methods course	Advanced science methods course	Introductory science methods course	Advanced science methods course	Introductory science methods course	Advanced science methods course
Observation	25.0	41.9	63.3	48.4	11.7	9.7
Classification	23.3	32.3	60.0	58.1	16.7	9.7
Quantification	35.0	32.3	51.7	51.6	13.3	16.1
Measurement	28.3	38.7	60.0	48.4	11.7	12.9
Inferring	20.0	35.5	66.7	48.4	13.3	16.1
Communication	26.7	35.5	58.3	45.2	15.0	19.4
Formulating hypothesis	23.3	35.5	63.3	48.4	13.3	16.1
Experimenting	18.3	35.5	55.0	45.2	26.7	19.4
Making operational definition	30.0	35.5	55.0	48.4	15.0	16.1
Interpreting data	28.3	32.3	60.0	48.4	11.7	19.4
Predicting	23.3	32.3	63.3	54.8	13.3	12.9
Controlling variables	25.0	32.3	60.0	58.1	15.0	9.7
Using space/ time relations	33.3	29.0	55.0	51.6	11.7	19.4

Table 6 below shows the percentage comparison of the introductory science methods course and advanced science methods course levels of conceptual understanding in science processes. Table 6 shows that very few pre-service teachers in both groups had "correct" answers. A majority had "partially correct" answers. This shows that a large number of pre-service teachers did not have a complete conceptual understanding of the science processes. Furthermore, table 6 shows that pre-service teachers had a great difficulty defining the process skills of quantification, inferring, communication, formulating hypothesis, experimenting, making operational definitions, interpreting data, predicting, controlling variables and using space/time relations.

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Table 6. Participants' conceptual understanding of process skills for the two courses.

Science Process Skill	Incorrect		Partially Correct		Correct	
	Introductory science methods course	Advanced science methods course	Introductory science methods course	Advanced science methods course	Introductory science methods course	Advanced science methods course
Observation	15.0	16.1	85.0	83.9	0.0	0.0
Classification	8.3	16.1	90.0	77.4	1.7	6.5
Quantification	50.0	48.4	50.0	51.6	0.0	0.0
Measurement	23.3	29.0	76.7	67.7	0.0	3.2
Inferring	75.0	67.7	25.0	32.3	0.0	0.0
Communication	61.7	22.6	38.3	74.2	0.0	3.2
Formulating hypothesis	41.7	67.7	58.3	25.8	0.0	6.5
Experimenting	61.7	35.5	36.7	61.3	1.7	3.2
Making operational definition	88.3	93.5	11.7	6.5	0.0	0.0
Interpreting data	55.7	51.6	43.3	35.5	0.0	12.9
Predicting	40.0	64.5	58.3	35.5	1.7	0.0
Controlling variables	88.3	96.8	11.7	3.2	0.0	0.0
Using space/ time relations	95.5	100.0	3.3	0.0	1.7	0.0

From section 3 of the questionnaire, pre-service teachers showed technical ways in which they did not exhibit complete conceptual understanding of the science processes. A large number of pre-service teachers had incomplete answers. Listed below were some of the findings:

- It was noted that many participants failed to distinguish between predicting and inferring.
- They also could not distinguish between quantification and measurement.
- A number of pre-service teachers used tautology in defining the terms in almost all categories.
- A number of pre-service teachers used everyday language in defining communication.
- There was frequent use of the phrase "educated guess" on formulating hypothesis, prediction and inferring. However, it was more especially on formulating hypothesis.
- Observation was mainly defined in terms of senses with sense of sight being most prevalent. No mention of extensions to technological aspects of observations.
- Classification was defined mainly on basis of similarities ignoring differences.
- In measurement there was no explicit mention of measuring tools.
- In experimenting, often pre-service teachers were not explicit in the practical aspects of the process.

- In controlling variables, they mentioned what is done instead of defining it as a process of identifying what to manipulate or keep constant.
- In defining Inferring, they mostly based it on a topic or knowledge instead of the observed data.
- In defining interpretation, mostly the pre-service teachers did not refer to the treatment or interpretation of data.

Discussion

The purpose of this study was to examine primary school pre-service teachers' familiarity, interest and conceptual understanding of the science processes. The results show that primary school pre-service teachers perceived themselves as being familiar with science processes. However, these teachers were not very interested in knowing more about science processes. Furthermore, their definitions and explanations revealed that they did not have complete conceptual understanding of the science processes. They had difficulties in defining and explaining processes such as quantification, inferring, communicating, formulating hypothesis, experimenting, making operational definitions, interpreting data, predicting, controlling variables and using space/time relations. These findings imply that these pre-service teachers' claims of familiarity with science processes did not corroborate with their abilities to define and explain the processes. Although some pre-service teachers in our study gave traditional and correct definitions of some basic science process skills such as observations and classifications, the presence of additional incorrect statements suggest that some participants just rote-learned the definitions. Similarly, Duit (1984) argued that it is difficult to distinguish whether even partially correct definitions and explanations of a concept provided by research participants are based on their understanding or merely rote-learned.

To a large extent, the results in this study are in keeping with previous studies on science process skills involving different groups of teachers and students. For example, Emereole (2009) also found that pre-service high school science teachers did not have sufficient conceptual knowledge of science process skills. Similarly, studies on teacher understanding of inquiry have reported that teachers of different grade levels lack sufficient understanding of science process skills (Lotter, Harwood, & Bonner, 2007; Luft, 2001).

Our results also show that most pre-service teachers were not very interested in knowing more about science processes. This finding confirms research-based assertion that primary school teachers lack sufficient content knowledge, inquiry knowledge, and do not possess positive attitude towards science (Crawford, 2000). These deficiencies do not promote a positive and effective science learning environment in schools. Other studies have concluded that a poor attitude towards science prevents teachers from actively and effectively teaching it (Osborne, Osborne, Simon & Collins, 2003). Yet, teacher competence in the science process skills has been found to promote a positive attitude towards science among students (Luft, 2001).

The results in this study and those in previous studies have implications for primary science teaching and teacher education. For example these pre-service teachers claimed they were familiarity with science processes, had low interest in the science processes and did not exhibit a high conceptual understanding. How do we expect these teachers to be effective science teachers if they don't understand science process skills they are supposed to teach their students? What can teacher educators do in order to harness teachers' potentials? Lack of teachers' interest and conceptual understanding of science process skills can impede effective science teaching in schools. Further, such teachers would not be able to create laboratory experiences that would help students develop science process skills. They would also not be able to teach the students the required process skills effectively.

Therefore, there is a need to find ways of transforming teachers' interest into conceptual

understanding of the science processes. Based on these results, we recommend an explicit intervention on science process skills in our teacher education program for pre-service teachers to develop interest and conceptual understanding of the science processes outlined in the national science education reforms and standards. As such, it is important to alert teacher educators to the fact that even those pre-service teachers who claim to be familiarity with science process skills may not have adequate understanding of the processes. Teacher educators should identify pre-service teachers' prior ideas about science processes in science methods courses. We also recommend future research to examine in-service teachers' familiarity, interest and conceptual understanding of science process skills.

Conclusions

The results in this study showed that primary school pre-service teachers had higher familiarity and some interest levels in science process skills, but very poor conceptual understanding of the science process skills. Their incorrect definitions of science processes ranged from not having any idea to tautology. Moreover, most participants interchanged definitions of some science processes notably measuring and quantification; and predicting and inferring. As such, there was a gap between their claims of familiarity with process skills and their ability to provide reasonable conceptual definitions and explanations of the science process skills. This group of pre-service teachers did not have sufficient conceptual knowledge of science process skills to help their future students to understand them in a meaningful way.

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Adviced by Naglis Švickus, SMC "Scientia Educologica", Lithuania

Simeon Mbewe	Graduate Research Assistant, Southern Illinois University, Dept. of Curriculum and Instruction, 625 Wham Drive, MC 4160, Carbondale, IL 62901, USA. E-mail: smbewe@siu.edu Website: http://www.siuc.edu
Vivien Mweene Chabalengula	Dr., Lecturer of Science Education, Southern Illinois University, Dept. of Curriculum and Instruction, 625 Wham Drive, MC 4160, Carbondale, IL 62901, USA. E-mail: mweene@siu.edu Website: http://www.siu.edu/
Frackson Mumba	Dr., Associate Professor of Science Education, Southern Illinois University, Dept. of Curriculum and Instruction, 625 Wham Drive, MC 4160, Carbondale, IL 62901, USA. E-mail: frackson@siu.edu Website: http://www.siu.edu/