February 2019

Elementary Education In-service Teachers' Familiarity, Interest, Conceptual Knowledge and Performance on Science Process Skills

Frackson Mumba

University of Virginia, fm4v@virginia.edu

Erin Miles

Southern Illinois University Carbondale

Vivien Chabalengula

University of Virginia, mweene@virginia.edu

Follow this and additional works at: <https://ir.library.illinoisstate.edu/jste>

Part of the [Science and Mathematics Education Commons](#), and the [Teacher Education and Professional Development Commons](#)

Recommended Citation

Mumba, Frackson; Miles, Erin; and Chabalengula, Vivien (2019) "Elementary Education In-service Teachers' Familiarity, Interest, Conceptual Knowledge and Performance on Science Process Skills," *Journal of STEM Teacher Education*: Vol. 53 : Iss. 2 , Article 3.

DOI: <https://doi.org/10.30707/JSTE53.2Mumba>

Available at: <https://ir.library.illinoisstate.edu/jste/vol53/iss2/3>

This Article is brought to you for free and open access by ISU ReD: Research and eData. It has been accepted for inclusion in Journal of STEM Teacher Education by an authorized editor of ISU ReD: Research and eData. For more information, please contact ISUReD@ilstu.edu.

Elementary Education In-Service Teachers' Familiarity, Interest, Conceptual Knowledge and Performance on Science Process Skills

Frackson Mumba
University of Virginia

Erin Miles
Southern Illinois University Carbondale

Vivien Chabalengula
University of Virginia

ABSTRACT

Although studies have examined teachers' science process skills, little is known about the extent to which in-service elementary teachers are familiar with science process skills and are interested in learning more about science process skills. Therefore, the purposes of this research study were to determine (a) in-service elementary teachers' familiarity with, interest in, conceptual knowledge of, and performance on science process skills and (b) how in-service elementary teachers' familiarity with, interest in, conceptual knowledge of, and performance on science process skills relate to each other. Forty-eight elementary teachers in 21 schools in the United States participated in this study. Data were collected using the Familiarity With Science Process Skills Questionnaire, the Conceptual Knowledge of Science Process Skills Test, the Science Process Skills Performance Test, and the Interest in Science Process Skills Survey. Results indicate that most teachers expressed high levels of familiarity with science process skills. Teachers performed well on the Science Process Skills Performance Test. In contrast, teachers demonstrated low conceptual knowledge of the science process skills. However, teachers expressed high levels of interest in learning more about science process skills. Specifically, teachers showed a significantly higher interest in learning more about the integrated process skills than the basic process skills. Correlations among familiarity, conceptual knowledge, performance, and interest were only significant between familiarity and interest. These findings have implications for science teaching, learning, and teacher education.

Keywords: Conceptual understanding; Familiarity; Interest; Science process skills; Teacher

In the United States, the *Framework for K-12 Science Education* (National Research Council [NRC], 2012) and the *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013) emphasize science process skills through science practices in K–12 science classrooms. These science education reforms and standards also suggest that K–12 students should combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science and scientific inquiry process. Likewise, the science education community encourages teacher preparation programs to emphasize science process skills to develop science

teachers who are competent in teaching science through inquiry (Capps, Crawford, & Conostas, 2012; Lotter et al., 2018). However, research studies continue to show that many elementary science teachers lack science process skills (Morrison, 2013; Plummer & Ozcelik, 2015). This is a major concern in the United States, where most elementary teachers have less coursework in science. Yet, science process skills are essential for teaching science content knowledge and scientific inquiry (Nivalainen, Asikainen, & Hirvonen, 2013; Oh, 2011). As such, science educators have raised doubt about whether elementary teachers can effectively teach science process skills to their students (Gunckel, 2013; Mbewe, Chabalengula, & Mumba, 2010). As elementary science teachers, they must make pedagogical decisions that can promote meaningful science content learning and development of science processes skills in students. Therefore, the success of providing quality inquiry science instruction in elementary schools will largely depend on teachers' science process skills and their implementation of science inquiry activities that enhance students' science process skills. Marshall, Smart, and Alston (2017) pointed out that science process skills foster significant increases in students' science content knowledge. They further argued that science content and science process skills should be taught together because they complement each other. Similarly, Nugent et al. (2012) asserted that both science content and science process skills are mutually valuable and complementary. Kang, Bianchini, and Kelly (2013) also underscored how science process skills provide a foundation for inquiry. Therefore, elementary education teachers' sufficient understanding of science content knowledge and science process skills are essential elements for effective inquiry science teaching in their science classrooms. On the other hand, teachers who are deficient in science process skills are less equipped to use inquiry in their classrooms (Marshall, Horton, Igo, & Switzer, 2009). Likewise, teachers' who are not familiar with science process skills or have low or no interest in science process skills are unlikely to teach science using inquiry and, subsequently, fail to develop science process skills in their students.

Teacher competence in science process skills has also been found to promote a positive attitude toward science. For example, Downing & Filer, 1999) reported that teachers who had a low understanding of science process skills are less likely to have a positive attitude toward them and are, therefore, less likely to teach them to their students. The avoidance of teaching science process skills can be detrimental because science process skills instruction also promotes positive attitudes toward science in students (Qureshi, Vishnumolakala, Southam, & Treagust, 2017). Therefore, teachers must be adequately prepared in science process skills as well as be familiar with and have sound conceptual knowledge of science process skills to effectively teach them to their students.

Although several studies have examined teachers' science process skills, little is known about the extent to which in-service elementary teachers are familiar with science process skills and their levels of interest in learning more about science process skills. We did not find a study that examined teachers' levels of familiarity with and interest in learning more about science process skills emphasized in science education reforms and standards. Yet, research shows that teachers' familiarity with and interest in subject matter knowledge or skills have influence on their instructional practice and, subsequently, on student achievement (Marshall, Smart, & Alston, 2017). As such, it is possible to assume that teachers who are not familiar with or are less interested in learning more about science process skills are unlikely to teach them well in their science classes and, subsequently, affect student's acquisition of process skills and understanding of science concepts. Familiarity with science subject matter knowledge contributes to teachers' pedagogical content knowledge for effective science teaching. Similarly, individuals interest in science have may have

significant influence on their desire to learn more about its content and scientific processes. As such, elementary teachers' willingness to learn more about science process skills or teach them to their students may largely depend on their interest in them. Interest is significant in determining how individuals choose and process certain types of information in preference to others (Hidi, 1990). It is also argued that when learners have a well-developed individual interest, they strive to maximize learning because they need to have positive feelings about the learning material.

In view of the above, examination of elementary education teachers' levels of familiarity with science process skills and their interest in learning more about them is needed because it may contribute to better inquiry science teaching and learning in schools. Additionally, examination of elementary teachers' interest in science process skills may serve as a measure of their willingness to learn more about them. Therefore, the purposes of this research study were to determine (a) in-service elementary teachers' familiarity, interest, conceptual knowledge of, and performance on science process skills and (b) how in-service elementary teachers' familiarity with, interest in, conceptual knowledge of, and performance on science process skills relate to each other. This study focused on elementary education teachers' familiarity with, interest in, conceptual knowledge of, and performance on basic and integrated process skills that are prescribed in science education reforms (NRC, 1996, 2012) and school science curriculum. The basic science process skills are *observing, measuring, classifying, inferring, predicting, and communicating*. The integrated science process skills are *interpreting data, identifying and controlling variables, graphing, formulating models, hypothesizing, and experimenting* (NRC, 1996).

Research Questions

This study was guided by the following research questions:

1. What are elementary science teachers' levels of familiarity, understanding, performance, and interest in learning more about science process skills emphasized in K–12 science education reforms?
2. Are there differences between and within elementary science teacher subgroups' familiarity, conceptual knowledge, performance, and interest in learning more about science process skills?
3. What is the relationship between elementary science teachers' familiarity, conceptual knowledge, performance, and interest in learning about science process skills?

Significance of the Study

This study is significant for four reasons. First, this study contributes to the existing literature on science process skills, teacher understanding of science process skills, and inquiry-based science teaching and learning. Second, it expands the current literature by examining elementary education teachers' familiarity with and interest in science process skills, which have not been addressed in previous research studies. As such, the science education community may find the relationship between teachers' familiarity, interest, and conceptual knowledge and performance useful in science teaching and learning. Third, the findings of this study are of significance to science teachers, school administrators, science teacher educators, science curriculum designers, professional development providers, and science education researchers. For example, science teacher educators' awareness of elementary teachers' familiarity with and interest in the science process skills can greatly influence their decisions in planning science content and methods courses

for elementary preservice teachers and professional development programs for in-service teachers. As such, the findings in this study have the potential to contribute to better development of pre- and in-service teachers' science process skills by making explicit their importance in science education overall. Further, teacher educators can use the science process skills in such a manner to demonstrate and, subsequently, teach their necessity in doing inquiry activities. As a result, elementary teachers would be better equipped to do inquiry and teach their students science process skills and, consequently, help students reap the immense benefits that solid understanding of these skills provide. Science curriculum developers could use the results as guides to develop effective inquiry-based science activities and units for elementary teachers and students. Science teachers would become aware of what needs to be improved with regard to teaching of science process skills in elementary science classrooms. Similarly, school administrators would become aware of how they can support their teachers to effectively teach science process skills and science using inquiry. Science education researchers may use the findings of this study as the starting points for further research on science process skill in teacher education and science classrooms.

Literature Review

Teachers' Science Process Skills

Research studies on teachers' science process skills range from teachers' understanding to their attitudes toward science. For example, Karsli, Sahin, and Ayas (2009) reported that teachers seriously lacked understanding of science process skills, and the application of science process skills by these teachers were dependent upon their ability to perform them. Teachers that did not use the science process skills or did not understand the science process skills gave standard excuses such as time or resources. Similarly, Farsakoğlu, Şahin, Karsli, Akpınar, and Ültay (2008) found that preservice teachers could not comprehend and describe the science process skills adequately and confused the skills with Blooms Taxonomy, problem solving, and Piaget's Formal Operational Stage. Emereole (2009) also found that high school teachers did not have sufficient conceptual knowledge of science process skills to help their students understand scientific inquiry in a meaningful way. Further, students' and teachers' views of science processes did not corroborate their demonstrated ability to provide acceptable conceptual definitions of the processes.

Other studies have examined the association between teachers' science process skills and their attitudes toward science (e.g., Downing & Filer, 1999; Palmer, 2004). For example, Downing and Filer (1999) found a moderate relationship between teachers' science process skills and attitudes toward science, leading to the conclusion that the better a teacher performs on science process skills, the better his or her attitude is toward science. Research continues to point out the impact of positive attitudes on teaching science; therefore, teacher education programs should emphasize the science process skills.

Inquiry and Science Process Skills in Science Classrooms

Several studies have explored the relationship between teachers' inquiry-based science instruction and student achievement. For example, Bilgin (2006) found that in addition to a more positive development of science process skills, attitudes toward science process skills were more positive in students who had a hands-on inquiry approach than those who did not. Similarly, Geier et al. (2008) reported that science curriculum emphasizing inquiry increased gains on achievement

tests for students. Mehalik, Doppelt, and Schunn (2008) also found that inquiry enhanced students' achievement in science and retention, particularly for minority groups. Minner, Levy, and Century (2010) reviewed research studies on inquiry and concluded that inquiry increased students' conceptual understanding, and just over half of the studies showed "positive impacts of some level of inquiry science instruction on student content learning and retention" (p. 487). Similarly, Emden and Sumfleth (2016) also reported that science process skills are essential to doing inquiry because they provide foundation to science learning.

Summary

Studies show that most teachers lack sound understanding of science process skills and that there are positive relationships between teachers' understanding of science process skills, their attitudes toward science, and student achievement. However, little is known about elementary school teachers' levels of familiarity and interest in learning more about the science process skills prescribed in science education reforms and standards. As such, this study extended previous studies on teachers' understanding of science process skills by exploring elementary education in-service science teachers' levels of familiarity with, conceptual knowledge of, performance on, and interest in learning about basic and integrated science process skills.

Methodology

Participants

The sample comprised 48 elementary education in-service teachers in 21 elementary schools in the Midwestern United States. All the teachers were certified to teach Grades 1–8. Most of the teachers were teaching science and other core subjects, including language arts and mathematics. Their teaching experience ranged from 5 to 20 years. There were 12 males and 36 females. In the United States, elementary education teachers don't specialize in one subject areas like secondary school science teachers do; however, they have one or two concentration areas in which they take more content courses. Although elementary teachers don't specialize in science like secondary school science teachers, we can assume that they learn more about science content knowledge and science process skills as they teach their students.

Data Collection Instruments and Procedures

Data were collected using four instruments that were developed by the authors: the Familiarity With Science Process Skills Questionnaire, the Conceptual Knowledge of Science Process Skills Test, the Science Process Skills Performance Test, and the Interest in Science Process Skills Survey. First, the 13-item Familiarity With Science Process Skills Questionnaire was administered to rate their familiarity with each science process skill by choosing "Term Not familiar to me"; "Term Familiar to me but not understood"; or "Term Familiar to me, and I understand its meaning." Second, teachers responded to the 13-item Conceptual Knowledge of Science Process Skills Test. They were asked to define, describe, or explain each science process skill in their own words. Third, the 48-item multiple-choice Science Process Skills Performance Test was administered to teachers to assess their performance on the 13 science process skills studied in this study. This test was written in a multiple-choice format, with each item having four possible answers to choose from. The test was developed using questions from the Test of Integrated Process Skill II (Burns, Okey, & Wise, 1985), the Test of Basic Process Skills (Padilla, Cronin, & Twiest, 1985), and the

Figure 1. Question 22, which asked participants to fit an item into a provided classification system.

Virginia Standards of Learning Assessments (Virginia Department of Education, 2007a, 2007b). Each multiple-choice item was correlated with a specific science process skill. The compilation of questions was done to obtain a wide variety of questions and skills. Of the 48 questions, 19 questions (39.6%) focused on the six basic process skills and 29 questions (60.4%) focused on the seven integrated process skills. At least three questions addressed each science process skill to gain multiple opportunities to examine performance on a science process skill. For example, questions on *classifying* asked participants to fit an item into a provided classification system (see Figure 1) and how they would classify a group of items (see Figure 2).

Some questions provided scenarios and asked subsequent questions attending to multiple skills, thereby increasing the total number of items for some skills. For example, Questions 5–8 all referred to a scenario about growing tomato plants and addressed the skills of hypothesizing, controlling variables, and identifying variables. Finally, the 13-item Interest in Science Process Skills Survey was administered to teachers to measure their levels of interest in learning more about science process skills. They rated their interest in learning more about each science process skills by choosing one of the following: “Not at all interested in learning more,” “Interested in learning more,” or “Very interested in learning more.”

Instrument Reliabilities and Validities

Reliability of the familiarity and interest instruments, and conceptual knowledge and performance tests were determined by computing Cronbach’s alpha (α) values. Cronbach’s alpha values were 0.923 for the Familiarity With Science Process Skills Questionnaire, 0.917 for the Interest in Science Process Skills Survey, 0.783 for the Conceptual Knowledge of Science Process Skills Test, and 0.762 for the Science Process Skills Performance Test. These values are acceptable measures of reliability because they are more than 0.70 the threshold value of acceptability as a measure of reliability (Cohen, 1988). Content and construct validities of the instruments were

Question 40: Charlie and Carole collected a basket of shells. They wanted to sort the shells into 2 groups. What would be the best way to sort them?

- A. By shape
- B. By age
- C. By color
- D. By where they were found

Figure 2. Question 40, which asked participants how they would classify a group of items.

established with the help of three science education experts. They independently checked for the extent to which the items in the instruments were assessing the science process skills prescribed in science education reforms and standards. On construct validity, the same experts looked at whether the questions in the instruments were worded so that the research participants could understand them. Table 1 shows the interrater measure of agreement of the three experts on the performance test items. The kappa values were high, and interrater measures were significant for all three raters of the test items.

Data Analysis

Participants' responses to items in the Familiarity With Science Process Skills Questionnaire and the Interest in Science Process Skills Survey were assigned a score. For the familiarity questionnaire, "Term Not familiar to me" was assigned a score of 1; "Term Familiar to me but not understood" was assigned a score of 2; and or "Term Familiar to me, and I understand its

Table 1
Interrater Measure of Agreement on Performance Test (N = 48)

Rater comparison	Cohen's kappa	Asymptotic standard error	Approximate T ^b	p-value
R1 vs. R2	.840	.056	18.983	.000*
R1 vs. R3	.727	.068	16.852	.000*
R2 vs. R3	.724	.068	16.170	.000*
Average	.764	.064	17.335	.000*

Note. R1 = Rater 1, R2 = Rater 2, and R3 = Rater 3.

* $p < .05$.

Table 2
Standard Descriptions of Science Process Skills Surveyed in This Study

Science process skill	Description
Basic science process skills	
Classifying	The process of grouping or ordering objects or events into categories based on properties, characteristics, criteria, or an established scheme.
Predicting	Stating the outcome of a future event based on a pattern of evidence, past experience, or observations.
Inferring	The process of making suggestions, conclusions, assumptions, or explanations about a specific event based on observation and data.
Measuring	The process of using standard and nonstandard measures or estimates and their appropriate instruments to describe the dimensions of an object, substance, or event in quantitative terms.
Communicating	The process of using words, symbols, graphics, and other written or oral representations to describe and exchange information, such as an action, object or event, from one person or system to another.
Observing	The process of using the five senses to gather information about an object or event.
Integrated science process skills	
Interpreting data	The process of treating or transforming data through finding patterns, graphs, or tables in order to make it meaningful and draw conclusions from it.
Experimenting	The process of determining and executing reasonable procedures to test an idea or hypothesis using observation, identifying and controlling variables, collecting and interpreting data, measuring, and manipulating materials.
Hypothesizing	Stating a verifiable relationship between variables and their expected outcome in an experiment or problem to be solved
Formulating models	The process of creating a mental, pictorial, written or physical representation to explain an idea, object, or event.
Identifying variables	Stating the changeable factors that can affect an experiment.
Controlling variables	Identifying any factors other than the manipulated variable that may affect the outcome of an event and keeping those factors constant for the purpose of determining causation.
Graphing	Using information about the data as numerical quantities and converting into a diagram or picture that shows the relationships among the quantities.

meaning” was assigned a score of 3. Similarly, for the interest survey, “Not at all interested in receiving more information” was assigned a score of 1, “Interested in receiving more information” was assigned a score of 2, and “Very interested in receiving more information” was assigned a score of 3. Participants’ responses to Conceptual Knowledge of Science Process Skills Test items were scored by matching participants’ responses with the standard definitions, explanations, and descriptions of the process skills (see Table 2). Standard definitions, explanations, and descriptions of the 13 science process skills were developed by researchers using several research articles (e.g., Emereole, 2009; Lancour, 2004; Valentino, 2000) and science textbooks devoted to science

process skills (e.g., Chiappetta & Koballa, 2010; Ostlund, 1992; Rezba, Sprague, McDonnough, & Matkins, 2007).

A correct response included a similar definition, explanation, or description (a verbatim response was not required). A partially correct response included at least some but not all key terms or ideas found in the standard description; included some explanation, definition, or derivatives of such ideas; and showed an incomplete understanding of the science process skill. An incorrect response did not include key terms or ideas or was unrelated or irrelevant to the science process skill. A correct response received a score of 3, a partially correct response received a score of 2, and an incorrect response received a score of 1. Two science education experts independently analyzed teachers' responses to items in the Conceptual Knowledge of Science Process Skills Test using the procedure described above. Then, the two met to compare and discuss their analyses. Some minor differences that emerged in their analyses were resolved through sustained discussions and re-examination of teachers' responses and standard responses. An intercoder agreement coefficient was calculated using Cohen's kappa (Cohen, 1960). This coefficient factors in chance agreement and represents a measure of reliability. The percentage agreement between the two raters for the teachers' responses to conceptual understanding test item analyses ranged from 86.7% to 92.9% with a corresponding range of kappa values from 0.81 to 0.90. These statistics suggest a high degree of agreement between the two raters in categorizing teachers' responses as correct, partially correct, or incorrect. According to Chiappetta, Fillman, and Sethna (1991), interrater agreement values above 75% indicate excellent percentage agreement, and kappa values below 0.4 indicate a poor interrater coefficient. Thereafter, means were calculated for correct, partially correct, and incorrect responses in the test. A total score was computed for each participant. Then, statistical tests were performed on the three data sets to test for differences between and within groups. Pearson correlation coefficients were computed to determine the extent to which teachers' familiarity with, interest in, and conceptual knowledge of science process skills and their performance on science process skills were related. We used nonparametric tests to analyze the data because the number of participants in each subgroup was small and because the data from the familiarity questionnaire and the interest survey were ordinal in nature.

Results

Teachers' Familiarity With Science Process Skills

Overall, most teachers (74%) said that they were familiar with the 13 science process skills and understood their meanings (see Table 3). About 92% of teachers reported that they were familiar with and understood the meaning of *observing* and *predicting*, and 88% indicated that they were familiar with and understood the term *measuring*. In the integrated process skills category, more than 75% of teachers reported that they were familiar with and understood the meaning of *hypothesizing*, *experimenting*, *interpreting data*, and *graphing*. However, 33% of teachers said that they were familiar with *formulating models* but did not understand its meaning. Table 4 shows that there was no significant difference ($U = 9.5, p > .05$) between teachers' familiarity ratings for the basic and integrated science process skills. This implies that teachers were as familiar with basic process skills as they were with integrated process skills. Further analysis on teachers' familiarity ratings compared teachers' familiarity with science process skills across demographic variables. As shown in Table 5, tests revealed no significant differences in familiarity ratings across the demographic variables. These results suggest the homogeneity of this group.

Table 3

Frequencies and Percentages for Teachers' Familiarity With the Science Process Skills (N = 48)

Science process skill	Term not familiar to me	Term familiar to me but not understood	Term familiar to me, and I understand its meaning
Basic science process skills			
Observing	2 (4.2%)	2 (4.2%)	44 (91.7%)
Classifying	2 (4.2%)	8 (16.7%)	38 (79.2%)
Measuring	2 (4.2%)	4 (8.3%)	42 (87.5%)
Inferring	2 (4.2%)	16 (33.3%)	30 (62.5%)
Predicting	2 (4.2%)	2 (4.2%)	44 (91.7%)
Communicating	2 (4.2%)	10 (20.8%)	36 (75.0%)
Mean	2 (4.2%)	7 (14.6%)	39 (81.3%)
Integrated science process skills			
Hypothesizing	2 (4.2%)	8 (16.7%)	38 (79.2%)
Experimenting	2 (4.2%)	6 (12.5%)	40 (83.3%)
Identifying variables	2 (4.2%)	12 (25.0%)	34 (70.8%)
Formulating models	2 (4.2%)	30 (62.5%)	16 (33.3%)
Interpreting data	2 (4.2%)	10 (20.8%)	36 (75.0%)
Controlling variables	2 (4.2%)	20 (41.7%)	26 (54.2%)
Graphing	2 (4.2%)	10 (20.8%)	36 (75.0%)
Mean	2 (4.2%)	13.7 (28.6%)	32.3 (67.3%)
Overall mean	2 (4.2%)	10.6 (22.1%)	35.4 (73.7%)

Conceptual Knowledge of Science Process Skills

Table 6 indicates that teachers possessed moderate to low conceptual knowledge of science process skills. The science process skill in which teachers possessed the highest conceptual knowledge was *experimenting* ($M = 2.29$). Teachers provided quality statements in defining *experiment*, using terms that indicated key terms of the standard definition such as “procedures,” “test a hypothesis,” and “using other process skills.” Statements such as “testing a problem using a scientific inquiry procedure . . . use control and variables” (Teacher 15) and “to test an idea to

Table 4

Comparison of Teachers' Familiarity With Basic and Integrated Science Process Skills (N = 48)

Type of skill	Mean	SD	Mean rank	Sum of ranks	U	W	Z	p-value
Basic	66.5	2.74	8.92	53.5	9.5	37.5	-1.657	.101
Integrated	63.1	4.22	5.36	37.5				

* $p < .05$.

Table 5

Comparison of Teachers' Familiarity Across Demographic Variables (N = 48)

Demographic variable		<i>n</i>	Mean rank	χ^2	<i>df</i>	<i>p</i> -value
Teaching experience (years)	1–5	14	10.14	2.554	2	.279
	6–10	12	16.17			
	11+	22	12.00			
Grades taught	1 & 2	6	11.17	.226	2	.875
	3 & 4	22	13.23			
	5	20	12.10			
Number of college science courses taken	0–1	4	14.50	1.787	3	.618
	2–3	24	12.04			
	4–5	12	10.42			
	6+	8	16.00			

* $p < .05$.

see if it is valid using observations, tasks, and data” (Teacher 19) were scored as partially correct, receiving a score of 2. The science process skills in which teachers possessed the lowest conceptual knowledge were *measuring* (1.29) and *hypothesizing* (1.38). These results are interesting because teachers reported *measuring* as one of the skills that they are most familiar with (see Table 3). For example, one teacher defined *measuring* as: “giving a scale of weight, length, volume, etc.

Table 6

Mean Scores on Conceptual Knowledge of Science Process Skills (N = 48)

Science process skill	Mean score	<i>SD</i>
Basic science process skills		
Classifying	2.25	0.79
Predicting	2.13	0.54
Communicating	2.00	0.51
Observing	1.92	0.72
Inferring	1.67	0.87
Measuring	1.29	0.44
Integrated science process skills		
Experimenting	2.29	0.81
Identifying Variables	2.25	0.53
Interpreting data	1.96	0.91
Formulating models	1.63	0.82
Graphing	1.63	0.71
Hypothesizing	1.38	0.58

Table 7

Percentages of Correct Responses on Conceptual Knowledge of Science Process Skills (N = 48)

Science process skill	Incorrect	Partially correct	Correct
Observing	29.2%	50.0%	20.8%
Classifying	20.8%	33.3%	45.8%
Measuring	70.8%	29.2%	0.0%
Inferring	58.3%	16.7%	25.0%
Predicting	8.3%	70.8%	20.8%
Communicating	12.5%	75.0%	12.5%
Hypothesizing	66.7%	29.2%	4.2%
Experimenting	20.8%	29.2%	50.0%
Identifying Variable	4.2%	66.7%	29.2%
Formulating models	58.3%	20.8%	20.8%
Interpreting data	41.7%	20.8%	37.5%
Graphing	50.0%	37.5%	12.5%
Overall Mean	36.8%	39.9%	23.3%

to something for further statistics” (Teacher 23). This teacher used the terms *weight*, *length*, and *volume* but failed to explain what these vocabularies mean and how they fit within the concept of *measuring*. Very few teachers used words such as *quantity* or *standard*, key features of the definition of *measuring*. One teacher (Teacher 14) used the word *measurement* in the definition itself. In defining the term *hypothesize*, most teacher responses (35 out of 48) included the terms *guess* or *educated guess*. Only one teacher mentioned *relationship*, specifically stating “to predict possible outcomes based on cause and effect” (Teacher 5). These excerpts also show that the elementary teachers used everyday language in describing science process skills.

Table 7 shows the percentage distribution of correct, partially correct, and incorrect performance of teachers. Overall, teachers had limited conceptual knowledge of the science process skills. As shown in Table 8, there was no significant difference in teachers’ conceptual knowledge between basic and integrated process skills. Teachers showed limited conceptual knowledge of both basic and integrated science process skills. Similarly, Table 9 shows there were no significant differences across demographics for conceptual knowledge. Teaching experience and number of college science courses taken did not make a difference in their ability to articulate basic and integrated science process skills.

Table 8

Comparison of Teachers’ Conceptual Knowledge Between Basic and Integrated Process Skills (N = 48)

Type of skill	Mean	SD	Mean rank	Sum of ranks	U	W	Z	p-value
Basic	45	8.34	6.42	38.5	17.5	38.5	-.080	.937
Integrated	44.5	8.94	6.58	39.5				

* $p < .05$.

Table 9

Comparison of Teachers' Conceptual Knowledge Across Demographic Variables

Demographic variable		<i>n</i>	Mean rank	χ^2	<i>df</i>	<i>p</i> -value
Teaching experience (years)	1–5	14	12.50	.294	2	.863
	6–10	12	11.25			
	11+	22	13.18			
Grades taught	1 & 2	6	10.00	1.497	2	.473
	3 & 4	22	14.36			
	5	20	11.20			
Number of college science courses taken	0–1	4	12.00	2.040	3	.564
	2–3	24	10.92			
	4–5	12	13.08			
	6+	8	16.63			

* $p < .05$.**Performance on Science Process Skills**

Overall, teachers performed well on the Science Process Skills Performance Test with individual scores ranging from 81% to 98% (see Table 10). For example, teachers performed well on the skills of *classifying* (98.4%), *interpreting data* (98.2%), and *experimenting* (98.1%). However,

Table 10

Percentages of Correct Responses on the Science Process Skills Performance Test (N = 48)

Science process skill	Number of items	Correct responses
Basic		
Classifying	3	98.4%
Predicting	3	97.3%
Inferring	3	96.5%
Measuring	4	90.6%
Communicating	3	86.7%
Observing	3	82.7%
Integrated		
Interpreting data	3	98.2%
Experimenting	4	98.1%
Hypothesizing	5	94.4%
Formulating models	2	94.3%
Identifying variables	7	88.0%
Controlling variables	4	68.3%
Graphing	4	61.2%

Table 11
Percentages for Incorrect Responses on the Performance Test

Science process skills tested	Number of items	Incorrect responses (%)
Classifying, communicating, experimenting, graphing, hypothesizing, inferring, interpreting data, measuring, observing, predicting	16	0
Classifying, experimenting, formulating models, hypothesizing, identifying variables, interpreting data, measuring, predicting	11	4
Identifying variables, formulating models, communicating	3	8
Controlling variables, graphing, identifying variables, inferring	8	12
Controlling variables	1	16
Hypothesizing, graphing, observing	3	20
Identifying variables	1	24
Controlling variables, communicating	2	32
Observing, measuring	2	36
Graphing	1	44

some teachers performed low on *graphing* (38.8%), *observing* (17.3%), and *controlling variables* (31.7%). Table 11 reports the percentages of incorrect responses on the test items. Overall, teachers performed well on the Science Process Skills Performance Test, demonstrating competence in the science process skills. However, statistical tests revealed no significant differences across demographics on performance (see Table 12).

Interest in Science Process Skills

Table 13 shows that elementary teachers expressed high levels of interest in learning more

Table 12
Comparison of Teachers' Performance Across Demographic Variables ($N = 48$)

Demographic variable	<i>n</i>	Mean rank	χ^2	<i>df</i>	<i>p</i> -value
Teaching experience (years)	1–5	11.07	.802	2	.670
	6–10	11.67			
	11+	13.86			
Grades taught	1 & 2	12.33	.057	2	.972
	3 & 4	12.86			
	5	12.15			
Number of college science courses taken	0–1	12.00	2.165	3	.539
	2–3	10.67			
	4–5	15.67			
	6+	13.50			

* $p < 0.05$.

about science process skills. For example, teachers were most interested in learning more about *graphing* and *identifying variables*, both are integrated science process skills, and *inferring*, which is a basic science process skill. Table 14 shows a significant difference ($U = 4.5, p < .05$) between teachers' interest in basic and integrated process skills. Overall, teachers showed a significantly higher interest in learning more about the integrated process skills than basic process skills. In contrast, there were no significant differences in interest ratings across demographic variables (see Table 15). These results suggest the homogenous nature of this group.

Relationship of Teachers' Familiarity, Interest, Conceptual Knowledge, and Performance

The results presented in Table 16 show that there was a significant relationship between teachers' familiarity with and interest in learning more about science process skills. Although no other relationships were significant, it is interesting to note the negative relationship between familiarity and conceptual knowledge, familiarity and performance, and interest and conceptual knowledge. These negative relationships suggest that the more familiar teachers claimed to be with the process skills, the lower their conceptual knowledge and performance on these skills were,

Table 13
Percentages for Teachers' Interest in Science Process Skills

Science process skill	Not at all interested in learning more	Interested in learning more	Very interested in learning more
Basic			
Observing	16.7%	58.3%	25.0%
Classifying	16.7%	58.3%	25.0%
Measuring	16.7%	58.3%	25.0%
Inferring ^a	12.5%	62.5%	25.0%
Predicting	12.5%	58.3%	29.2%
Communicating	8.3%	54.2%	37.5%
Mean	13.9%	58.3%	27.8%
Integrated			
Hypothesizing	8.3%	58.3%	33.3%
Experimenting	4.2%	50.0%	45.8%
Identifying variables ^a	4.2%	62.5%	33.3%
Formulating models	8.3%	45.8%	45.8%
Interpreting data	4.2%	58.3%	37.5%
Controlling variables ^a	4.2%	50.0%	41.7%
Graphing ^a	12.5%	62.5%	25.0%
Mean	6.6%	55.3%	37.5%
Overall mean	10.0%	56.7%	33.0%

^a Science process skills teachers expressed in learning more.

Table 14

Comparison of Interest Between Basic and Integrated Science Process Skills

Type of skill	<i>n</i>	Mean	<i>SD</i>	Mean rank	Sum of ranks	U	W	Z	<i>p</i> -value
Basic	6	51.33	1.97	4.25	25.5	4.5	25.5	-2.39	.014*
Integrated	7	55.14	2.27	9.36	65.5				

* $p < 0.05$.

and the same is true for interest and conceptual knowledge to a lesser extent. Further, teachers' performance on science process skills tasks required the use of conceptual knowledge, and the two have a positive relationship even though it is not significant. This implies that even if teachers are more familiar with science process skills, their low conceptual knowledge may affect their performance on science process skills.

Discussion and Conclusions

Results show that in-service elementary teachers reported high levels of familiarity with both basic and integrated science process skills on the Familiarity With Science Process Skills Questionnaire. They performed well on the Science Process Skills Performance Test. However, they demonstrated moderate to low conceptual knowledge on the Conceptual Knowledge of Science Process Skills Test. On the Interest in Science Process Skills Survey, they expressed high levels of interest in learning more about science process skills. In particular, teachers rated the science process skills that they were least familiar with as the ones that they were most interested in learning more about. Thus, this group of teachers appeared to be open to addressing their deficiencies in conceptual knowledge of science process skills. Only familiarity and interest were significantly correlated, whereas other variables had negative or positive relationships that were not significant.

Table 15

Comparison of Teachers' Interest Across Demographic Variables

Demographic variable		<i>n</i>	Mean rank	χ^2	<i>df</i>	<i>p</i> -value
Teaching experience (years)	1–5	14	10.50	.826	2	.662
	6–10	12	13.33			
	11+	22	13.32			
Grades taught	1 & 2	6	11.67	.209	2	.901
	3 & 4	22	12.05			
	5	20	13.25			
Number of college science courses taken	0–1	4	12.25	.012	3	1.00
	2–3	24	12.63			
	4–5	12	12.50			
	6+	8	12.25			

* $p < 0.05$.

Table 16
Pearson Correlation Coefficient Between Instruments

	Interest	Conceptual knowledge	Performance
Familiarity	.640*	-.030	-.118
Interest		-.005	.077
Conceptual knowledge			.385

* $p < 0.01$.

Science process skills are of the utmost necessity for doing inquiry (Breslyn & McGinnis, 2012), student science achievement (Qureshi et al., 2017), understanding of the nature of science, and scientific literacy (Colvill & Pattie, 2002). As such, elementary teachers must possess an adequate level of knowledge on science process skills so that they can effectively teach them to their students. Unfortunately, this group of teachers demonstrated a low conceptual knowledge of the science process skills, with most responses on the conceptual knowledge test being incorrect or partially correct. This finding is consistent with those reported in previous studies. For example, Emereole (2009) found that teachers reported they were highly familiar with the science process skills, but their conceptual knowledge was very low. Similarly, Farsakoğlu et al. (2008) found that teachers could not adequately define or describe science process skills. The low conceptual knowledge held by teachers in previous studies and the present study should be a call to action on the part of science teacher education and professional development programs. Previous research suggests that teachers who lack science process skills or have a poor conceptual knowledge of science process skills are less equipped to use inquiry teaching strategies in their classrooms (Capps et al., 2012). Such teachers also may not be promoting a positive attitude toward science for students in their classrooms (Lotter et al., 2018; Morrison, 2013). Teacher education programs should refocus their science education courses to explicitly include and address science process skills during instruction, ensuring that teachers are entering the field adequately prepared to teach science and science process skills. Integrating science process skills instruction with instruction on inquiry will ensure that elementary teachers are prepared to effectively teach science.

In contrast with the results of the conceptual knowledge test, teachers did perform well on the science process skills test. This result could be because context plays a part in cognitive tasks presented in a test, especially on multiple choice tests (Song & Black, 1991). The performance test in this study presented these skills in a real-world type situation, possibly assisting teachers in doing them because they were familiar with the contexts. However, more research should be done to validate this claim.

Previous studies have focused on performance of science process skills under the assumption that proficiency on performance represents sound understanding of science process skills. However, the results of the present study indicate that these teachers possessed low levels of conceptual knowledge of the science process skills despite performing well on the science process skills test. The fact that teachers performed well on context-based science process skills items and poorly on the conceptual knowledge test indicates that teachers may be teaching these skills implicitly rather than explicitly because the multiple-choice test implies a skill and does not explicitly ask teachers to demonstrate cognitive competence as the conceptual knowledge test does. An implicit instructional approach limits the opportunity for students and teachers alike to gain a deeper

understanding of science content and skills. Additionally, such an instructional approach prevents science process skills from having the greatest educational impact on students in terms of inquiry, science achievement, scientific literacy, and an understanding of the nature of science.

There was a significant correlation between familiarity and interest; however, there was a negative correlation between familiarity and performance. It is also interesting to note that the skills teachers reported being familiar with were the skills on which they had the lowest performance. For example, teachers rated *observing* as one of the two skills that they were most familiar with, but it was one of the skills on which they performed the lowest (only two skills had lower performance). These results mimic the correlation results that indicated familiarity and performance had a negative correlation. Teachers may be teaching these skills because they are familiar with them but may be teaching them incorrectly or with misconceptions, as indicated by their performance on the conceptual knowledge test.

Another major outcome of this study was the teachers' ratings and performance on the skill of *experimenting*. This science process skill received high ratings and scores in all the data sources. A possible explanation for this is that these teachers explicitly teach this skill more than the other skills, thus increasing their familiarity with, conceptual knowledge of, and performance on this skill. Because they frequently teach this skill, they are also likely to be interested in learning more about it.

Looking more specifically at individual skills, teachers had a low conceptual knowledge of and performance on the skill *graphing*. This finding is in line with results reported in previous research on teachers' graphing skills. For example, Roth, McGinn, and Bowen (1998) reported that preservice teachers have graphing difficulties, and such difficulties were attributed to a lack of appropriate training in graphing skills. Teachers also performed low on the *measuring* skill. This is also consistent with findings that suggest difficulties with the task of measuring. For example, Rollnick, Lubben, Lotz, and Dlamini (2002) found that students were unable to measure accurately and appropriately in lab experiments both prior to and after instruction and hands-on activities. Even though the elementary teachers in this study were teaching science, their teaching experience did not seem to translate well to the cognitive tasks, indicated by their low conceptual knowledge of science process skills that were emphasized in school science curriculum. Teachers' low conceptual knowledge of most process skills should inform teacher preparation programs of elementary education teachers' deficiencies in science processes that are essential for inquiry science teaching and learning. Teacher education programs should emphasize that there are a variety of skills that depend on each other and that each skill should be taught and emphasized equally. Programs should also emphasize that basic skills are a necessity to understanding integrated skills such as *experimenting* and that focusing on only some integrated skills misses the opportunity to provide a rich and complete understanding of science for teachers and their students.

Based on our results, we suggest the following five areas for future research on science process skills in teacher education. First, explore why this group of teachers performed well on a performance test despite showing low conceptual knowledge. Second, extend this study to a greater pool of participants, including pre- and in-service secondary science teachers and their students. An understanding of teachers and students science process skill familiarity, interest, conceptual knowledge, and performance will allow for researchers to compare students and teachers to better determine the extent of the influence that teachers have on their students' science process skills. Third, employ a mixed-methods approach by collecting both quantitative and qualitative data.

Qualitative data should include classroom observations, science lesson activity analysis for process skills, and interviews. Fourth, investigate teachers' attitudes toward specific science process skills because attitude can have a significant impact on what teachers teach and how they teach it, both positively and negatively. Fifth, examine the relationship between conceptual knowledge of the process skills and how that translates into classroom instruction and use of the science process skills.

In conclusion, most teachers expressed high levels of familiarity with science process skills, and teachers performed well on the Science Process Skills Performance Test. In contrast, teachers demonstrated low conceptual knowledge of the science process skills. However, teachers expressed high levels of interest in learning more about science process skills. Specifically, teachers showed a significantly higher interest in learning more about the integrated process skills than basic process skills. Correlations among familiarity, conceptual knowledge, performance, and interest were only significant between familiarity and interest.

References

- Bilgin, I. (2006). The effects of hands-on activities incorporating a cooperative learning approach on eight grade students' science process skills and attitudes toward science. *Journal of Baltic Science Education*, 5(1), 27–37.
- Breslyn, W., & McGinnis, J. R. (2012). A comparison of exemplary biology, chemistry, earth science, and physics teachers' conceptions and enactment of inquiry. *Science Education*, 96(1), 48–77. doi:10.1002/sce.20469
- 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. doi:10.1002/tea.3660220208
- Capps, D. K., Crawford, B. A., & Constan, M. A. (2012). A review of empirical literature on inquiry professional development: Alignment with best practices and a critique of the findings. *Journal of Science Teacher Education*, 23(3), 291–318. doi:10.1007/s10972-012-9275-2
- Chiappetta, E. L., Fillman, D. A., & Sethna, G. H. (1991). A method to quantify major themes of scientific literacy in science textbooks. *Journal of Research in Science Teaching*, 28(8), 713–725. doi:10.1002/tea.3660280808
- Chiappetta, E. L., & Koballa, T. R., Jr. (2010). *Science instruction in the middle and secondary schools: Developing fundamental knowledge and skills for teaching* (7th ed.) Columbus, OH: Pearson.
- Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement*, 20(1), 37–46. doi:10.1177/001316446002000104
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.
- Colvill, M., & Patti, I. (2002). Science skills—The building blocks for scientific literacy. *Investigating: Australian Primary & Junior Science Journal*, 18(3), 20–30.
- Downing, J. E., & Filer, J. D. (1999). Science process skills and attitudes of preservice elementary teachers. *Journal of Elementary Science Education*, 11, (2), 57–64. doi:10.1007/BF03173838
- Emden, M., & Sumfleth, E. (2016). Assessing students' experimentation processes in guided inquiry. *International Journal of Science and Mathematics Education*, 14(1), 29–54. doi:10.1007/s10763-014-9564-7

- Emereole, H. U. (2009). Learners' and teachers' conceptual knowledge of science processes: The case of Botswana. *International Journal of Science and Mathematics Education*, 7(5), 1033–1056. doi:10.1007/s10763-008-9137-8
- Farsakoğlu, Ö. F., Şahin, Ç., Karsli, F., Akpınar, M., & Ültay, N. (2008). A study on awareness levels of prospective science teachers on science process skills in science education. *World Applied Sciences Journal*, 4(2), 174–182.
- Geier, R., Blumenfeld, P. C., Marx, R. W., Krajcik, J. S., Fishman, B., Soloway, E., & Clay-Chambers, J. (2008). Standardized test outcomes for students engaged in inquiry-based science curricula in the context of urban reform. *Journal of Research in Science Teaching*, 45(8), 922–939. doi:10.1002/tea.20248
- Gunckel, K. L. (2013). Fulfilling multiple obligations: Preservice elementary teachers' use of an instructional model while learning to plan and teach science. *Science Education*, 97(1), 139–162. doi:10.1002/sce.21041
- Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research*, 60(4), 549–571. doi:10.3102/00346543060004549
- Kang, E. J. S., Bianchini, J. A., & Kelly, G. J. (2013). Crossing the border from science student to science teacher: Preservice teachers' views and experiences learning to teach inquiry. *Journal of Science Teacher Education*, 24(3), 427–447. doi:10.1007/s10972-012-9317-9
- Karsli, F., Şahin, Ç., & Ayas, A. (2009). Determining science teachers' ideas about the science process skills: A case study. *Procedia: Social and Behavioral Sciences*, 1(1), 890–895. doi:10.1016/j.sbspro.2009.01.158
- Lancour, K. L. (2004). *Process skills for life science (04): Training guide*. Oakbrook Terrace, IL: Science Olympiad National Office. Retrieved from https://scioly.org/wiki/images/d/d6/Pslsl_training_hammond04.pdf
- Lotter, C. R., Thompson, S., Dickenson, T. S., Smiley, W. F., Blue, G., & Rea, M. (2018). The impact of a practice-teaching professional development model on teachers' inquiry instruction and inquiry efficacy beliefs. *International Journal of Science and Mathematics Education*, 16(2), 255–273. doi:10.1007/s10763-016-9779-x
- Marshall, J. C., Horton, R., Igo, B. L., & Switzer, D. M. (2009). K-12 science and mathematics teachers' beliefs about and use of inquiry in the classroom. *International Journal of Science and Mathematics Education*, 7(3), 575–596. doi:10.1007/s10763-007-9122-7
- Marshall, J. C., Smart, J. B., & Alston, D. M. (2017). Inquiry-based instruction: A possible solution to improving student learning of both science concepts and scientific practices. *International Journal of Science and Mathematics Education*, 15(5), 777–796. doi:10.1007/s10763-016-9718-x
- Mbewe, S., Chabalengula, V. M., & Mumba, F. (2010). Pre-service teachers' familiarity, interest and conceptual understanding of science process skills. *Problems of Education in the 21st Century*, 22, 76–86. Retrieved from <http://oaji.net/pdf.html?n=2014/457-1400515680.pdf>
- Mehalik, M. M., Doppelt, Y., & Schunn, C. D. (2008). Middle-school science through design-based learning versus scripted inquiry: Better overall science concept learning and equity gap reduction. *Journal of Engineering Education*, 97(1), 71–85. doi:10.1002/j.2168-9830.2008.tb00955.x
- Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—What is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching*, 47(4), 474–496. doi:10.1002/tea.20347

- Morrison, J. A. (2013). Exploring exemplary elementary teachers' conceptions and implementation of inquiry science. *Journal of Science Teacher Education*, 24(3), 573–588. doi:10.1007/s10972-012-9302-3
- National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press. doi:10.17226/4962
- National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press. doi:10.17226/13165
- NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Washington, DC: National Academies Press. doi:10.17226/18290
- Nivalainen, V., Asikainen, M. A., & Hirvonen, P. E. (2013). Open guided inquiry laboratory in physics teacher education. *Journal of Science Teacher Education*, 24(3), 449–474. doi:10.1007/s10972-012-9316-x
- Nugent, G., Toland, M. D., Levy, R., Kunz, G., Harwood, D., Green, D., & Kitts, K. (2012). The impact of an inquiry-based geoscience field course on pre-service teachers. *Journal of Science Teacher Education*, 23(5), 503–529. doi:10.1007/s10972-012-9283-2
- Oh, P. S. (2011). Characteristics of abductive inquiry in earth science: An undergraduate case study. *Science Education*, 95(3), 409–430. doi:10.1002/sce.20424
- Ostlund, K. L. (1992). *Science process skills: Assessing hands-on student performance*. New York, NY: Addison-Wesley.
- Padilla, M., Cronin, L., & Twiest, M. (1985, April). *The development and validation of the test of basic process skills*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, French Lick, IN.
- Palmer, D. (2004). Situational interest and the attitudes towards science of primary teacher education students. *International Journal of Science Education*, 26(7), 895–908. doi:10.1080/0950069032000177262
- Plummer, J. D., & Ozcelik, A. T. (2015). Preservice teachers developing coherent inquiry investigations in elementary astronomy. *Science Education*, 99(5), 932–957. doi:10.1002/sce.21180
- Qureshi, S., Vishnumolakala, V. R., Southam, D. C., & Treagust, D. F. (2017). Inquiry-based chemistry Education in a high-context culture: A Qatari case study. *International Journal of Science and Mathematics Education*, 15(6), 1017–1038. doi:10.1007/s10763-016-9735-9
- Rezba, R. J., Sprague, C. R., McDonnough, J. T., & Matkins, J. J. (2007). *Learning and assessing science process skills* (5th ed.). Dubuque, Iowa: Kendall/Hunt.
- Rollnick, M., Lubben, F., Lotz, S., & Dlamini, B. (2002). What do underprepared students learn about measurement from introductory laboratory work? *Research in Science Education*, 32(1), 1–18. doi:10.1023/A:1015022804590
- Roth, W.-M., McGinn, M. K., & Bowen, G. M. (1998). How prepared are preservice teachers to teach scientific inquiry? Levels of performance in scientific representation practices. *Journal of Science Teacher Education*, 9(1), 25–48. doi:10.1023/A:1009465505918
- Song, J., & Black, P. J. (1991). The effects of task contexts on pupils' performance in science process skills. *International Journal of Science Education*, 13(1), 49–58. doi:10.1080/0950069910130105
- Valentino, C. (2000). *Developing science skills*. Retrieved from <http://www.eduplace.com/science/profdev/articles/valentino2.html>

Virginia Department of Education. (2007a). *Virginia standards of learning: Spring 2007 released test: Grade 3 science* (Form S0117, Core 1). Richmond, VA: Author. Retrieved from http://www.doe.virginia.gov/testing/sol/released_tests/2007/test07_science3.pdf

Virginia Department of Education. (2007b). *Virginia standards of learning: Spring 2007 released test: Grade 5 science* (Form S0117, Core 1). Richmond, VA: Author. Retrieved from http://www.doe.virginia.gov/testing/sol/released_tests/2007/test07_science5.pdf

Authors

Frackson Mumba

Associate Professor

Department of Curriculum, Instruction, and Special Education

University of Virginia

Email: fm4v@virginia.edu

Erin Miles

Southern Illinois University Carbondale

Email: devinanderinmiles@gmail.com

Vivien Chabalengula

Associate Professor

Department of Curriculum, Instruction, and Special Education

University of Virginia

Email: mweene@virginia.edu