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

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IN-SERVICE ELEMENTARY TEACHERS' FAMILIARITY, INTEREST, CONCEPTUAL KNOWLEDGE, AND PERFORMANCE ON SCIENCE PROCESS SKILLS

By

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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. The science process skills include the basic skills [observation, classification, measuring, predicting, inferring, and communication,] and the integrated skills [hypothesizing, experimenting, identifying and controlling variables, formulating models, interpreting data, and graphing].

Twenty-four in-service elementary teachers enrolled in a master of math and science education degree program participated in this study. Participants completed questionnaires on their familiarity and interest in the science process skills, a science processes conceptual knowledge test, and a performance test on science process skills. Results indicate that these teachers were highly familiar with the science process skills, but moderately interested in these skills. Results also indicate that teachers were more interested in learning more about integrated process skills than basic process skills. Teachers possessed very low conceptual knowledge of the science process skills. However, teachers performed well on science process skills performance test. Significant correlations among the four constructs (familiarity, interest, conceptual knowledge and performance) were only significant between familiarity and interest.

The implications, discussion and recommendations for future research and instruction on science process skills in teacher education programs have been presented.

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INTRODUCTION

Introduction

For over forty years, the United States' educational system has formally recognized science process skills as an integral topic of educational value for students at different grade levels. For example, the development of the ready-made science system *Science-A Process Approach* [S-APA] (AAAS, 1967) had widespread popularity throughout the late 1960s and 1970s and continued to inspire as more and more ready-made science systems emerged on the scene. Although most of these systems proved effective, no program quite emphasized the science process skills as did *S-APA.*

Similarly, current science education standards such as the National Science Education Standards (National Research Council [NRC], 1996), the Benchmarks for Scientific Literacy (American Association for the Advancement of Science [AAAS] (1993), Science for All Americans (AAAS, 1990), and the positional statement of the National Science Teachers Association (NSTA, 2002) all include clear recommendations for the inclusion of science process skills and their importance in developing scientifically literate citizens. Current science education reforms and standards have identified both basic and integrated science process skills. The basic process skills are *observing, classifying, predicting, inferring, measuring,* and *communicating.* Although there is some discussion about the extent of skills included in the integrated skills, most lists include *identifying and controlling variables, defining operationally, reading/constructing graphs, formulating hypotheses, interpreting data, experimenting,* and *formulating models* (Padilla, 1990). Likewise, recommendations by current science education reforms and standards make specific reference for teachers in teaching both basic and integrated science process skills (AAAS, 1990) and encourage teacher preparation programs to emphasize science process skills in an effort to develop teachers who are competent in teaching science through inquiry (NSTA, 2002).

Arguably, teachers must be adequately prepared in the science process skills, be familiar with, and have conceptual knowledge to effectively teach these skills to their students (Harlen, 1999). While there have been several research studies on the acquisition of science process skills by both teachers and students, and several studies on the interaction between achievement and science process skill performance, very few studies have examined the non-cognitive aspects of teachers' process skills, such as familiarity with or interest in the science process skills. Likewise, these studies have not compared cognitive and non-cognitive aspects of teachers' science process skills, leaving open the need for more understanding of how teachers view, use and understand these skills.

Problem Statement

As mentioned above, current USA science education reforms and standards require science teachers to teach science process skills to their students (AAAS, 1990, 1993; 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). Therefore, teachers' sufficient understanding of science processes, content knowledge, and inquiry are essential elements for effective science teaching in K-12 classrooms.

However, many studies over the years have demonstrated that elementary teachers lack science content knowledge and inquiry pedagogical skills to effectively teach science (Arzi & White, 2007; Fulp, 2002a & 2002b; Deng, 2007; Childs & McNicholl, 2007; Traianou, 2006; Summers, Kruger, & Child, 2001; Wheeler, 2007). Yet, science process skills are essential for teaching science content knowledge and scientific inquiry (Cain, 2002). Scharmann (1989) points out that science process skills foster significant increases in subject matter understanding and science content knowledge, arguing that science content and science process skills should be taught together as they complement each other. Similarly, Rillero (1998) points out that both science content and science process skills are mutually valuable and complementary. Settlage and Southerland (2007) also emphasize how the science process skills provide a foundation for inquiry.

Research suggests that teachers who are deficient in the science process skills are less equipped to use inquiry in their classrooms (Anderson, 2002; Blanchard, Southerland, & Granger, 2008; Hume, 2009; Lotter, Harwood, & Bonner, 2007; Marshall, Horton, Igo, & Switzer, 2009). Similarly, teachers' who are not familiar with science processes or have low interest in science processes are not likely to teach science by inquiry. Teacher competence in the science process skills has also been found to promote a positive attitude towards science (Downing, Filer, & Chamberlain, 1997). Teachers who have a poor understanding of the science process skills are less likely to have a positive attitude towards them and are, therefore, less likely to teach them to their students. The avoidance of teaching the process skills can be detrimental, as process skills instruction also promotes positive attitudes toward science among students (Bilgin, 2006).

Although studies have examined teachers' conceptual knowledge of the science process skills, no study has examined the extent to which in-service elementary 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 know in-service elementary teachers' conceptual knowledge of the science process skills, and their familiarity and interest in learning more about science process skills. These two non-cognitive constructs (familiarity & Interest) have an effect on science teaching because teachers are unlikely to teach science concepts or skills they are not familiar with or have no interest in. As such, there is need to examine teachers' levels of familiarity and interest in science process skills as well. Therefore, this study examined in-service elementary teachers' familiarity, interest, conceptual knowledge of and performance on basic science process skills (*observing, measuring, classifying, inferring, predicting and communicating)* and integrated science process skills (*interpreting data, identifying and controlling variables, using space/time (graph) relationships, formulating models, hypothesizing, and experimenting*).

Purpose of the Research

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.

Research Questions

1. To what extent are in-service elementary teachers familiar with science process skills?
2. To what extent are in-service elementary teachers interested in science process skills?
3. What is the in-service elementary teachers' conceptual knowledge of science process skills?
4. How well do in-service elementary teachers perform on science process skills?
5. To what extent are in-service elementary teachers' familiarity, interest conceptual knowledge and performance on science process skills related to each other?

Significance of the Study

The results of this study can be useful to science teacher educators in that an awareness of elementary teachers' familiarity with and interest in the science process skills can greatly influence teacher educators' decisions in planning teacher education program and courses. This information may help these science teacher educators to better promote and teach science process skills to both pre- and in-service teachers, 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. A better prepared curriculum will help teacher education programs address some of the more serious, general concerns such as subject matter content knowledge, inquiry understanding and use, and confidence towards teaching science. As a result, K-8 teachers will be better equipped to do inquiry and teach students the science process skills, and consequently help students reap the immense benefits that solid understandings of these skills provide.

This study also adds to the existing literature on the science process skills, teacher understanding of these skills and inquiry-based science teaching and learning. In addition, it expands current literature by addressing two constructs, elementary teachers' familiarity with and interest in science process skills, which were not addressed in previous research. Likewise, science education researchers may find the relationship between familiarity, interest, and cognitive aspects (conceptual knowledge and performance) of particular appeal.

Definition of Terms

Science process skills: A set of broadly transferable abilities appropriate to many science disciplines and reflective of the behavior of scientists (Padilla, 1990).

Observation: The process of using the five senses to gather information about an object or event (Padilla, 1990; Lancour, 2004; Valentino, 2000; Longfield, 2002; Ostlund, 1992; Chiappetta & Koballa, 2010; Funk, Fiel, Okey, Jaus, & Sprague, 1985).

Classification: The process of grouping or ordering objects or events into categories based on properties, characteristics, criteria, or an established scheme (Emereole, 2008; Padilla, 1990; Lancour, 2004; Valentino, 2000; Longfield, 2002; Ostlund, 1992; Chiappetta & Koballa, 2010; Funk et al., 1985; Gega & Peters, 1998).

Measurement: 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 (Lancour, 2004; Padilla, 1990; Ostlund, 1992;

Longfield, 2002; Chiappetta & Koballa, 2010; Gega & Peters, 1998).

Inferring: The process of making suggestions, conclusions, assumptions, or explanations about a specific event based on observation and data (Emereole, 2008; Lancour, 2004; Padilla, 1990; Valentino, 2000; Longfield, 2002; Ostlund, 1992; Chiappetta & Koballa, 2010; Funk et al., 1985; Gega & Peters, 1998).

Predicting: Stating the outcome of a future event based on a pattern of evidence, past experience, or observations (Emereole, 2008; Lancour, 2004; Padilla, 1990; Valentino, 2000; Rezba, Sprague, McDonnough, & Matkins, 2007; Longfield, 2002; Chiappetta & Koballa, 2010).

Communication: 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 (Emereole, 2008; Lancour, 2004; Padilla, 1990; Valentino, 2000; Longfield, 2002; Ostlund, 1992; Funk et al., 1985; Gega & Peters, 1998).

Hypothesizing: Stating a verifiable relationship between variables and their expected outcome in an experiment or problem to be solved (Emereole, 2008; Lancour, 2004; Padilla, 1990; Ostlund, 1992; Funk et al., 1985).

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 (Emereole, 2008; Valentino, 2000; Padilla, 1990; Longfield, 2002; Ostlund, 1992; Chiappetta & Koballa, 2010; Funk et al., 1985).

Identifying variables: Stating the changeable factors that can affect an experiment

(Emereole, 2008).

Formulating models: The process of creating a mental, pictorial, written or physical representation to explain an idea, object, or event (Lancour, 2004; Padilla, 1990; Longfield, 2002; Ostlund, 1992).

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 (Emereole, 2008; Padilla, 1990; Valentino, 2000; Longfield, 2002; Ostlund, 1992; Chiapetta & Koballa, 2010).

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 (Emereole, 2008; Padilla, 1990; Ostlund, 1992; Chiappetta & Koballa, 2010; Funk et al., 1985).

Graphing: Using information about the data as numerical quantities and converting into a diagram or picture that shows the relationships among the quantities (Ostlund, 1992; Funk et al., 1985).

Assumptions

This study is based on the following assumptions:

1. Participants will respond truthfully as to their familiarity with and interest in the science process skills.
2. The science process skills performance test is designed to only measure performance on science process skills.

Limitations

1. A small and convenient sample was used, hindering the generalizability of the results.
2. A sample comprised in-service teachers currently enrolled in a Masters Degree program for Mathematics and Science education. Therefore, these participants may have had more training in the science process skills than typical in-service teachers, again compromising the generalizability of the study.

CHAPTER 2

LITERATURE REVIEW

Introduction

This chapter presents a review of the literature on science process skills. First, a review of studies on improving teachers' understanding of process skills has been presented. Second, studies on the benefits of science process skills understanding such as improved science achievement have been presented. Third, the relationships of science process skills to the nature of science, scientific literacy, inquiry and achievement have been presented. Finally, the chapter presents the directions from the literature review.

Science Process Skills and Teachers

There have been many studies over the years that examined teachers' science process skills. These studies have ranged from teachers' understanding to attitudes towards science process skills. Many studies have also emphasized the importance of teachers' understanding of the science process skills. These studies have established a strong argument for ensuring such understanding. For example, in the development of a tool to measure science process skill performance, Burns, Okey, and Wise (1985) make a strong argument on the importance of science process skills, claiming "the process skills represent the rational and logical thinking skills used in science". Further, they argue that teachers must exhibit competence in the process skills in order to effectively teach them to children. Other research supports this claim. Ailello-Nicosia and ve Sperandeo-Mineo Valenza (1984) focused on middle school science teachers' understanding of the science process skills and tested their pupils at the end of the school year to determine the impact teachers' ability in the skills has on their students. Their results were not surprising, as they found that using the processes “is a more valuable teacher characteristic than the understanding of science processes for student outcomes”. This is a significant finding, as it indicates that teachers must not only have an understanding of the skills, but must be functionally literate in the skills in order to appropriately and effectively teach them to their students.

Despite a variety of studies that establish the importance of science process skills for teachers, there is evidence that teachers do not have sufficient knowledge and understanding of these skills. Pointing out that even though the science process skills are essential for student learning and beneficial because they are cross curricular, developed early in life, and are transferable thought processes, Sunal and Sunal (2003) contend that both children and adults lack the ability to use them appropriately. Other research that has focused on teachers, support this claim. For instance, Karsli, Sahin, and Ayas (2009) examined teachers’ ideas about the science process skills through open-ended questioning. His results indicate that teachers seriously lack an understanding of science process skills, particularly theoretically. He found that the application of science process skills by these teachers were dependent upon the teachers’ ability, and those that did not use the science process skills or did not understand the science process skills gave standard excuses such as time or resources. A similar study by Farsakoglu, Sahin, Karsli, Akpinar, and Ultay (2008) found that pre-service teachers could not comprehend the content of science process skills, could not describe the science process skills adequately, and confused the skills with Blooms Taxonomy, problem solving, and Piaget’s Formal Operational Stage. Emereole (2009), a study that lends itself highly to this one, found that high school teachers did not have sufficient conceptual knowledge of science process skills.

Each of these studies reiterates previous work that it is essential to provide training to teachers, both pre- and in-service, in the science process skills (Riley, 1979). As previously stated, this will improve teacher understanding of the process skills and provide teachers with the support they need to share these skills with their students (Harlen, 1999). Further, this will improve teacher confidence in the science process skills, making them more likely to teach them (Jaus, 1975). Improving elementary teachers' confidence in the science process skills is essential, as Chan (2002) pointed out, based on findings that teacher confidence in the skills overall is low to moderate. Likewise, improving teacher attitude is vital. Downing, Filer, and Chamberlain (1997) researched the relationship between science process skills and attitudes towards science. Moderate correlations were found between the two, leading to the conclusions that the better a teacher performs on science process skills, the better his or her attitude is towards science. Their findings suggest that teacher education programs should emphasize the science process skills, as previous research has pointed out the impact that positive attitudes have on teaching science (Palmer, 2004; Osborne, 2003; Rice, 2005; Ahtee & Johnston, 2006).

While teachers have been found to be deficient in this area, there is hope in changing the situation regarding teachers' use and understanding of science process skills. In earlier work, Campbell and Okey (1977) found that the ability of pre-service teachers to use science process skills could be altered. Teaching two courses, Campbell and Okey (1977) used process skill based instruction to teach one course, and did not teach the process skills in the other. They found that the group taught using process skills had significantly higher results regarding science process skill achievement, selecting more process skill oriented objectives, and including process skills in lesson plans. Other research has supported these results, indicating that science process skill development gains with instruction in the skill (Jaus, 1975; Foulds & Rowe, 1996). Bluhm's (1979) use of hands-on science process skill instruction with pre-service teachers yielded promising results. He found that science process skill achievement, defined as knowledge and ability to use, was significantly improved with hands-on instructional activities. His study supported the findings of Jaus (1975). Jaus (1975), in particular, provided integrated science process skill instruction to 90 pre-service elementary teachers. Instruction was provided via self-teaching pamphlets, completely accomplished by the learner, including practice activities and self-tests. Objective writing and science process skill achievement were then measured using questionnaires. The findings reveal that these instructional materials significantly improve teachers' integrated process skill achievement. Further, pre-service teachers in this study selected and wrote significantly more objectives aimed at these skills than did un-trained peers. These results suggest, as Jaus points out, that pre-service and in-service teachers attain competence in science process skills if they are provided the training. Likewise, Jaus concludes that "teachers competent in the science process skills design instructional materials that provide for similar process skill acquisition by children" (445). Overall, Jaus reiterates the vital message that teachers must be proficient in the science process skills because they design the activities that teach these skills to children.

Science Process Skills and Students

The science process skills must be understood by teachers so that they may impart on their students a lasting and valuable comprehension. The science process skills are vital for students and can be started very early in life. Several studies highlight that the basic science process skills can begin prior to Kindergarten (Kirch, 2007; Meador, 2003; Sunal & Sunal, 2003; Martin, Sexton, & Gerlovich, 2001). Lind (2002) stresses the importance of creating science process skills opportunities for early childhood students. She argues that the natural development and curiosity of children enable them to instinctively do the basic process skills such as observe, classify, collect and organize data, and measure. Although the teacher or parent might need to assist in small ways, such as recording information, the young child explores and experiments the phenomena he or she encounters in a manner that we know as the basic science process skills. In summary, Lind maintains that these skills are the building blocks of science process skills and are used by pre-Kindergarten and early elementary students through normal daily interaction. As such, this daily interaction provides students with basic understandings of science, possibly sparking an interest in science for the future.

Middle school students are also greatly impacted through the learning of the science process skills. Three studies, each roughly ten years apart, found similar results when examining middle school students' (sixth through eighth grade) achievement after science process skill instruction. The earliest, in 1984 by Padilla, Okey and Gerrard, found that instruction in the science process skills, particularly in the integrated process skills such as identifying and controlling variables, formulating hypotheses, and experimenting, are beneficial to the overall science achievement. Brotherton and Preece

(1996) also studied middle school students and found that an intervention with emphasis on the science process skills had lasting and persistent effects on science achievement. Likewise, Brotherton and Preece found the integrated skills had a significant difference in achievement for these students. In a similar study, Preece and Brotherton (1997) again found that teaching the science process skills in early secondary can have long-term positive effects on science achievement. Finally, Bilgin (2006) found that hands-on science process skill instruction increased eighth grade students' skills in a positive manner, along with increasing positive attitudes towards science. Other research, such as Molitor and George (1976), has found that students with science process skill training or instruction do markedly better than those with no training.

Not only are the science process skills important for science achievement, but are easily transferable to other subject areas as well. Several authors mention the cross-curricular nature of the science process skills (Sunal & Sunal, 2003; Martin et al., 2001; Rillero, 1998). Ostlund (1998) cites a multitude of studies that demonstrate how science process skills are related to reading abilities, reading readiness, and allows students also to better develop language skills. She goes on to discuss the many studies that demonstrate how the science process skills enhance both oral and written communication skill and language development of special needs students. Finally, Ostlund presents how the science process skills are essential to math, particularly helping students move from one cognitive development level to the next, enhance operational abilities, and enhance problem-solving skills. Ostlund points out that the science process skills are also coupled with critical thinking skills, which is likely the reason why the process skills lend themselves so readily to other subjects.

The science process skills are also strongly associated to logical thinking (Padilla, Okey & Dillashaw, 1983) and formal operational abilities (Padilla, 1991) in addition to critical thinking. Settlage and Southerland (2007) justify the purpose for teaching the skills by arguing that they provide students with active learning, sense-making tools, language development, a community of learners, and foster a natural sense of curiosity. Further, the science process skills are essential to scientific creativity and creative thinking. In an article concerning academically gifted elementary students, Meador (2003) links the science process skills to thinking like a scientist, and argues that both are essential for fostering creativity. Thus, she contends that creative thinking and science process skills are intertwined and those who use science process skills are better at scientific creativity. Creativity and higher mental processes also have a high likelihood of being transferred to other subject areas (Karsli, Sahin, & Ayas, 2009).

The benefits of science process skill instruction for students are eminent. The National Science Teachers Association (NSTA, 2002), in their position statement, explicitly states that teachers should create first-hand exploratory investigations that focus on inquiry and the process skills to enhance student learning. Students who have science teachers that are knowledgeable about the science process skills gain with appropriate and effective skill instruction. Likewise, students who are exposed to science process skill instruction demonstrate a higher level of science achievement and enhance their math and language arts abilities. Students provided with the process skill instruction tend to have and be able to use higher mental process and creativity. Therefore, science educators must develop teachers who are competent in the knowledge and teaching of the science process skills, to consequently ensure that students get effective and valuable skill instruction.

Science Process Skills and the Nature of Science

The nature of science is an element of the science curriculum that allows students the ability to fully understand how science as a discipline functions. Some of its tenets include that science is a way of understanding our world, science is a tentative and creative enterprise, and science is not a single method (Chiappetta & Koballa, 2010). It is important that we teach science process skills not only because of the aforementioned benefits to teachers and students, but also because of its link to the nature of science. In his chapter for Britton, Glynn, and Yeany's text, Padilla (1991) clearly points out that the process skills should be taught because they "more accurately reflect the nature of science and the typical activity of scientists" (212). He argues that activities based in the process skills provide students an opportunity to view the true nature of science through the perspective of a scientist.

Rowland, Stuessy, and Vick (1987) developed a workshop for in-service teachers to teach them the basic science process skills. In providing reasoning for teaching the process skills, the authors point out that a process approach 1) highlights that science is a way of understanding our world; 2) makes them do science as scientists do and 3) develops scientific attitudes. These factors are important as they emphasize that developing the science process skills in teachers is important if the educational community is to impart a positive attitude towards science on our students and demonstrate the nature of science to their students. Rezba, Sprague, McDonnough, and Matkins (2007) devotes an entire textbook to the science process skills and a sub-section to how the science process skills help teach the nature of science, and Rillero (1998) declares the process skills “promote an understanding of the nature of science” (p. 3), both citing similar reasons to Rowland et al. (1987).

While several research studies have mentioned how the science process skills are related to particular tenets of the nature of science, very few have explicitly looked at their relationship. Scharmann (1989) collected data from 135 pre-service teachers regarding three factors: introductory process instruction followed by integrated content and methods courses, process instruction followed separately with content and teaching method instruction, and no process instruction only content and teaching methods. His results indicate that science process skills instruction significantly increase understanding of the nature of science and science content knowledge. Further analysis revealed that content and the process skills should be instructed together, rather than a content versus process model, suggesting that instruction of one should complement the other.

Again, the benefits of the science process skills abound and the information presented should not be taken lightly. This information, compiled together, further strengthens the argument that science process skills are an essential piece of any science curriculum and to obtain maximum benefits from the learning of the skills, teachers must be adequately prepared to teach them.

Scientific Literacy and Science Process Skills

Ultimately science educators and organizations hold the goal of creating a scientifically literate society. Several textbooks, journal articles, and national organizations have emphasized how the science process skills contribute to overall scientific literacy. The American Association for the Advancement of Science, in their

Project 2061, set out to create a scientifically literate society by the year 2061. Science literacy is also supported by the National Science Education Standards (NRC, 1996) and the National Science Teachers Association. Science process skills are essential in attaining that goal.

Padilla (1991) cites the importance of science process skills because of their generalizability to life. Rillero (1998) points out that all jobs, not just those that are science related, require the use of science process skills. He further mentions that the process skills help us in the everyday decision we must encounter. Tasks such as observing, analyzing, and hypothesizing help us to understand the world around us and function, adapt, and proceed accordingly. Colvill and Pattie (2002) reiterate this point, again overtly discussing the importance and essential nature of the science process skills for scientific literacy.

Padilla (1990), in his statement on behalf of the NSTA, summed the ultimate target well, stating that "teachers need to select curricula which emphasize science process skills...[and] need to capitalize on opportunities in the activities normally done in the classroom" (Summary & Conclusion). Teachers must be proficient in the science process skills on a multitude of levels. We must and enable them with the knowledge, understanding and tools to teach the science process skills. The arsenal that is the process skills will enable our teachers, students, and ultimately our citizens to be scientifically literate, productive and functional beings in society.

Inquiry, Achievement, and Science Process Skills

Inquiry has been an integral part of science education for some years now. Like the process skills, inquiry is included in National Science Standards and reforms (NRC, 2000; AAAS, 1993). The importance of using inquiry of traditional methods holds a strong argument. Likewise, there have been numerous studies over the years on the topic of inquiry regarding its relationship to teachers, students, achievement, learning, understanding, and use. In general, studies report that the use of inquiry increases teacher confidence (Bhattacharyya, Volk, & Lumpe, 2009), understanding of the nature of science, and interest (Sanger, 2008) which lead to a greater chance that inquiry will be used in the classroom.

Studies on inquiry have also focused on its effect on students. For example, in a study examining the use of inquiry and its relationship to underrepresented students, such as minorities in urban areas, Geier et al. (2008) found that science curriculum that emphasized inquiry increased gains in achievement test. Mehalik, Doppelt, and Schunn (2008) found similar results in students for science concept learning, achievement, and retention particularly for minority groups. Wilson, Taylor, Kowalski, and Carlson (2010) also found that science instruction taught with inquiry methods increased achievement levels with lasting effects for students. Minner, Levy, and Century (2010) examined research on inquiry over a nearly twenty year span. Their review of these studies concluded that inquiry increases 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.” Further, the examinations of the ‘investigation cycle,’ or skills that are similar or have roots in the science process skills, are also indicative of better scientific conceptual learning. These studies are important because inquiry and the science process skills are interrelated, one is necessary for the other. Cain (2002) argues that the science process skills are essential to doing inquiry, because they are “basic to all later learning." In their first chapter on the basic process skills, Settlage and Southerland (2007) also link the science process skills to inquiry, mentioning that the skills are the foundation of scientific inquiry. Inquiry is a process-oriented approach, as defined by the National Science Education Standards (NRC, 2000), and includes five features, all of which can be met through the use of process skills. These five features are "understanding scientific concepts, an appreciation of 'how we know' what we know in science, understanding the nature of science, skills necessary to become independent inquirers about the natural world, [and] the dispositions to use the skills, abilities, and attitudes associated with science" (p. 105). The relationship between inquiry-based science instruction and the science process skills is evident. In a look at eighth grade students' science process skills and attitudes toward science, Bilgin (2006) compared students who were taught science process skills using a hands-on, inquiry type approach to those that were not. In addition to a more positive development of science process skills, the results indicated that the attitudes towards science process skills were more positive in students who had a hands-on inquiry approach than those who did not.

Directions from Literature Review

It is evident from the literature review presented above that several studies emphasize the importance of the science process skills for both students and teachers. This review also suggests that teachers have difficulties understanding science process skills and applying them in their classrooms. The studies demonstrate, however, that there is a relationship between a conceptual understanding of science process skills and achievement in science.

While a few studies have looked at the performance of teachers on the science process skills, or examined teachers' performance on the process skills in relation to process skill instruction, such studies were often one dimensional and focused only on the cognitive aspects. As such, research studies have not fully examined the extent to which elementary teachers are familiar with and interested in the science process skills.

Only one study has examined the familiarity of teachers with science process skills and their conceptual knowledge of skills (Emereole, 2009). Emereole asked teachers to rate their familiarity to specific science process skills and then define those terms, which subsequently served as a leading methodology and inspiration for the present study. However, Emereole's study did not examine teacher interest in these skills and did not examine performance on science process skills. Further, his study focused on pre-service and in-service secondary science teachers. The present study uses Emereole's (2009) research framework as a guide and aims to delve more in depth in comparing both cognitive (conceptual knowledge & performance) and non-cognitive aspects (familiarity and interest).

Specifically looking at studies that examined performance, much of the previous research used multiple choice item tests in order to evaluate performance on the process skills. Similarly, this study employed multiple choice tests to examine performance. Differing, however, the present research study included a rating instrument, in which teachers were provided the opportunity to express familiarity and interest with science process skills on a questionnaire, having three responses to choose from. Most previous studies reviewed in this chapter employed quantitative methods. A few also used qualitative means to obtain follow-up data. Thus, the present study also employed quantitative methodology. Recommendations were withstanding and focused on promoting the science process skills to pre-service teachers, in-service teachers, and students of all ages. Each study reviewed continued to reiterate the point that the science process skills are an essential piece to understand, both in science and beyond. Further, studies truly emphasized that teacher understanding of the science process skills is vital for improving the quality of education (Harlen, 1997).

Based on the main themes presented in this chapter, the present research study attempts to extend past research by examining the extent to which in-service K-8 teachers are familiar with science process skills, their levels of interest in science process skills, their conceptual understanding of science process skills and performance on science process skills.

CHAPTER 3

RESEARCH METHODOLOGY

Introduction

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. The following research questions were addressed:

1. To what extent are in-service elementary teachers familiar with science process skills?
2. To what extent are in-service elementary teachers interested in science process skills?
3. What is the in-service elementary teachers' conceptual knowledge of science process skills?
4. How well do in-service elementary teachers perform on science process skills?
5. To what extent are in-service elementary teachers' familiarity, interest, conceptual knowledge and performance on science process skills related to each other?

Context of the Study

This study was conducted in Science, Mathematics and Action Research for Teachers (SMART) graduate program at Southern Illinois University Carbondale (www.smart.siu.edu). This is a federal and state funded master's degree program. This graduate degree program was designed for K-8 math and science teachers. The main goals and objectives of the graduate program were:

Goals:

- Increase elementary school teachers' mathematics and science content and pedagogical knowledge.
- Increase elementary school teachers' knowledge and skills for conducting and applying educational research in their classrooms.
- Develop long-term relationships between teachers and Southern Illinois University Carbondale (SIUC) scientists and mathematicians.
- Enhance existing partnerships and create new ones among SIUC and LEAs in Southern Illinois.

Objectives:

- Develop an intensive graduate program for elementary school teachers to address mathematics and science (biology, chemistry, geology and physics) content and pedagogical knowledge, National and State Learning Standards, leadership, mentoring, and communication skills.
- Infuse inquiry-based approaches through assembling of inquiry-based integrated math and science courses for the graduate program.
- Promote reflective teaching practices among the teachers through Action research.
- Provide a continuous professional network support to teachers through face-to-face and online.

The framework of the degree program requires the participants to take foundation courses, advanced math and science content and pedagogical courses. The total credit hours for the degree are 36 hours. The foundation courses are broad in scope, and emphasize both integration of mathematics and science disciplines and integration of content strands within disciplines. Physical sciences (physics, chemistry, and earth science), biological sciences and mathematical sciences are all included. The content courses provide teachers with deeper content and pedagogical content knowledge of the mathematics and science topics appropriate to the elementary curriculum. Again, integration is emphasized: integration of mathematics and science disciplines; integration of content strands within disciplines; integration of technology as appropriate into the science and mathematics classroom; and integration of content and pedagogy. The education and pedagogy courses acquaint teachers with broader issues that are the subject of scientifically based research in mathematics and science education and provide the framework for them to develop and implement action research in their own classrooms. Educational leadership is also infused in these courses. Science courses emphasize both the content knowledge and inquiry-based teaching approaches. Mathematics courses emphasize content and problem solving methods.

This partnership comprises SIUC and more than eight school districts in southern Illinois. The partnership organizational structure, as illustrated in Figure 1, reflects a multi-level, interactive model that incorporates external expertise, administrative and organizational oversight and leadership, and a coordinated interdisciplinary educational network to innovatively meet the project goals and objectives.

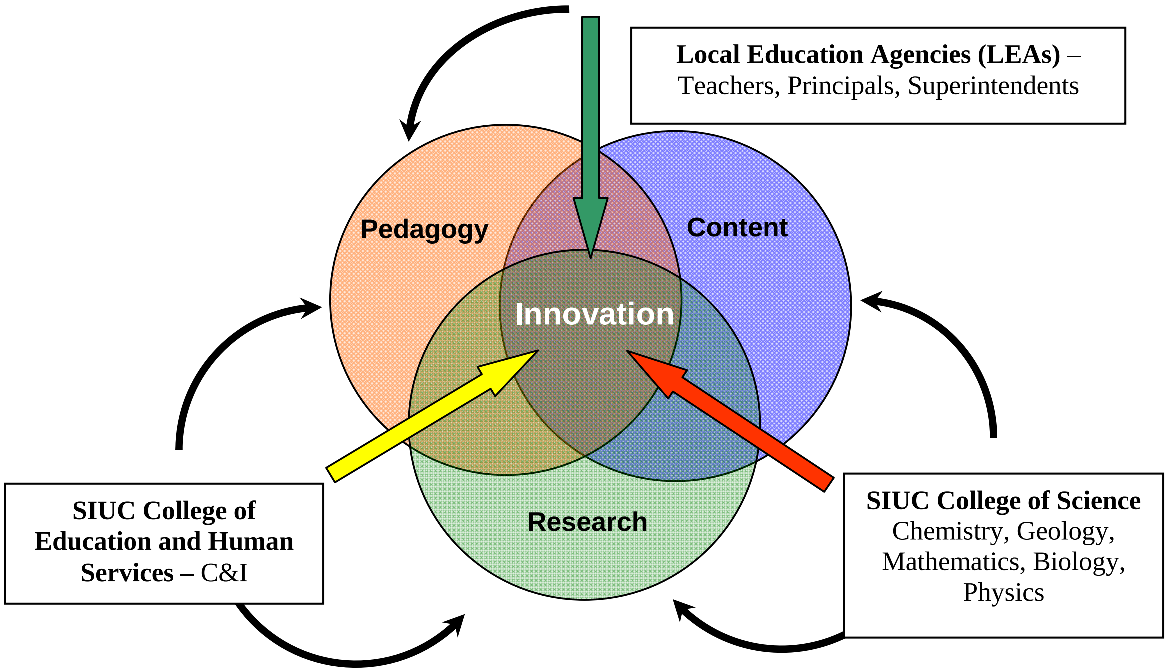

Figure 1: SMART Partnership Organizational Structure

Participants

The data was collected from a convenient sample. A sample consisted of 24 in-service elementary teachers in the southern Illinois area who were enrolled in a master of math and science education degree program described in Context of the Study section above. The degree program was supported by Illinois State Board of Education's Math and science partnership program. Participants had completed a total of 21 graduate credit hours, nine hours in math [Mathematical Topics for Teachers; Advanced Topics in the Teaching of Mathematics, Teaching Problem Solving in School Mathematics Grades K-8] and 12 hours in science [Science for Elementary School Teachers, Contemporary Biology for Teachers, Chemistry Topics for Teachers, Earth and Space Science for Teachers] and were enrolled in three credit hours of a physics course [Special Physics Topics for Teachers], at the time this study was being conducted.

The profiles of the participants are provided in Table 1 below. Participants' age ranged from 24 to 61. There were 22 females and two males. Three teachers taught in grade Kindergarten, first and second, eleven teachers taught in grades third, fourth, and fifth, and ten teachers taught in grades sixth, seventh, and eighth. Several teachers taught multiple grade levels. Two teachers taught grades fifth through eighth, one teacher taught sixth through eighth, and one teacher taught seventh and eighth. For ease, those that taught grades fifth through eighth were placed in the demographic category of "6-8" because the majority of the grade levels were in that category. Teaching experience ranged from three years to 25 years. The types of subjects taught, past teaching experience, and certificate endorsements were diverse among the participants.

Table 1

Participants' Profiles

Demographic	Division	Number of Participants	Percentage
Age	24-30	5	20.83%
	31-35	6	25%
	36-40	3	12.5%
	41-45	5	20.83%
	46+	5	20.83%
Teaching Experience	1-5 years	7	29.17%
	6-10 years	6	25%
	11+ years	11	45.83%
Grade Taught	K-2	3	12.5%
	3-5	11	45.83%
	6-8	10	41.67%
College Science Courses	3-6 courses	2	8.3%
	7-9courses	12	50%
	10-12courses	6	25%
	13+ courses	4	16.67%

N=24

Data Collection Instruments

Familiarity with and Interest in Science Process Skills Questionnaire

The preface to the questionnaire and test was a demographic page that determined the following: gender, age, teaching experience, grade level taught, self-contained classroom, subjects taught, past teaching experience, college science courses taken, undergraduate degree, and teaching endorsements.

The familiarity with and interest in science process skills questionnaire determined in-service elementary teachers' familiarity with and interest in science process skills. A copy of this questionnaire is provided as Appendix A. The format of the questionnaire was adapted from Shwartz, Ben-Zvi, and Hofstein (2006) with adaptations of format and content from Emereole (2009). Originally Shwartz, Ben-Zvi, and Hofstein's (2006) instrument was used to determine the chemical literacy levels of high school students in Israel. Emereole's (2009) study asked participants to rate fifteen basic and integrated process skills as very familiar, uncertain, and not familiar (Emereole, 2009). The current study's questionnaire was broken into two parts in which participants responded to their familiarity and interest in the following science process skills: *observation, classification, measuring, inferring, hypothesizing, experimenting, identifying variables, formulating models, interpreting data, predicting, controlling variables, graphing,* and *communication. In* part A participants were asked to mark each skill as "term not familiar to me," "term familiar to me but not understood," or "term familiar to me and I understand its meaning." In part B participants were asked to mark each skill as "not at all interested in learning more," "interested in learning more," or "very interested in learning more."

Conceptual Knowledge of Science Process Skills Test

The conceptual knowledge science process skills test examined teachers' conceptual knowledge of science process skills by asking them to define or explain the following science process skills *observe, classify, measure, infer, hypothesize, experiment, variable, model, interpret data, predict, communication,* and *graphing.* A copy of this test is provided as Appendix B. The format was also adapted from Shwartz, Ben-Zvi, and Hofstein (2006) with adaptations of format and content from Emereole (2009) in which participants were asked to define or explain particular chemical terms and science process skills, respectively. Similarly, in this study participants were asked to define or explain the science process skills in their own words in relation to science. The process skills on this instrument were worded slightly different from verbs in the *Familiarity with and Interest* in Science Process Skills Questionnaire to nouns in the Conceptual Knowledge of Science Process Skills Test, to make more sense to the participants. For example, controlling variables and identifying variables are verbs, whereas variable is a noun and can be easily defined.

Science Process Skills Performance Test

The science process skills performance test was used to determine teachers' performance on science process skills items. A copy of this instrument in provided as Appendix C. This test was written in a multiple choice format, with each item having 4 possible answers to choose from. This instrument uses multiple choice questions from the Test of Integrated Process Skill II by Burns, J.C., Okey, J.R., & Wise, K.C. (1985), the Test of Basic Process Skills by Padilla, M., Cronin, L., & Twiest, M. (1985), the Virginia Standards of Learning Assessments (Virginia Department of Education, 2007, used with permission see Appendix D) and the National Assessment of Education Progress (2005) from the US Department of Education. Each multiple choice item was correlated with a specific science process skill, determined either by the original instrument author or, when not available, the researcher.

The instrument is a compilation of 48 questions from four instruments. 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. The researcher attempted to obtain at least three questions to address each skill to gain multiple opportunities to examine performance on a particular skill without fatiguing the participants. By compiling all the questions and arranging them according to the skill they addressed, the research then picked out several questions that assessed the particular skill using a variety of formats. For example, questions on *classification* asked participants how they would classify a group of items (see Question 40 in appendix C) and to fit an item into a provided classification system (see Question 22 in appendix C). 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 (see appendix C) all refer to a scenario about growing tomato plants and address the skills of *hypothesis, controlling variables,* and *identifying variables.*

Data Collection Procedures

Data was collected during two sessions, both of which were during scheduled meetings of the physics course. The instruments were administered by one of the Principal Investigators of the SMART program. Participants were informed to write their names on the instrument and that all data would be kept confidential and would, in no way, be associated with their course grade. Participants were also informed that participation was voluntary.

In the first session, participants were asked to complete the demographic form, the Familiarity with and Interest in Science Process Skills Questionnaire, and the Conceptual Knowledge on Science Process Skills Test. In the second session, participants were given the Science Process Skills Performance Test and bubble-form sheet. They were told to write their names on the bubble-form sheet and to answer the questions to the best of their abilities. They were reminded that the performance on the test was in no way associated with their grade. Participants were not timed for either data collection session in order to obtain the best responses from the group. Participants completed session one on familiarity, interest, and conceptual knowledge within one hour. Participants also completed session two, the performance on science process skills test, within one hour.

Instrument Reliabilities and Validities

The first instrument, familiarity with and interest in science process skills questionnaire yielded a Cronbach alpha reliability coefficients of 0.953 for familiarity with science process skills and 0.957 for interest in science process skills. The Conceptual Knowledge of Science Process Skills Test was found to have a Cronbach reliability coefficient of 0.743. Coding was completed by the researcher and another science education expert in an attempt to eliminate bias and was found to have a Cohen’s kappa inter-rater reliability of .250 as seen in Table 2 below. The instrument was coded independently at different times, possibly influencing the reliability since the raters were unable to discuss their coding with each other at the time of coding.

Table 2

Inter-Rater Measure of Agreement on Conceptual Knowledge Test

Kappa Value	N	Asymp. Std. Error	Approx. T^b	Sig.
.250	288	.047	5.902	.000

The Performance on Science Process Skill Test was a compilation of test items from published reliable and valid process skill performance tests. The Cronbach alpha reliability coefficient of the performance on science process skills test used in this study was .305. This low reliability value may be attributed to the nature of the test in that although it measures the process skills, it measures thirteen different skills that are both basic and integrated. Low variance in scores could also cause a low reliability coefficient and is much more likely in a group of this small sample size. To ensure instrument validity of the compilation, three qualified science education experts from the Department of Curriculum and Instruction at Southern Illinois University Carbondale evaluated the Performance on Science Process Skills Test. The professionals were given a copy of the instrument, a copy of the process skills and were asked to identifying each question with its associated process skill. A Cohen's kappa score of .764 indicates a strong inter-rater reliability for the instrument. The results of this reliability test are presented in Table 3 below. The professionals were also asked to supply any comments or changes to the instrument. The comments yielded only one change to the instrument in which a question referenced a picture/drawing. The picture was found to be confusing because of the placement of a line, and the line was moved to make the picture clearer. Once changes were completed content validity was assumed with no other validity tests performed thereafter.

Table 3

Inter-Rater Measure of Agreement on Performance Test

Rater comparison	Kappa Value	N	Asymp. Std. Error	Approx. T^b	Sig.
R1 v R2	.840	48	.056	18.983	.000
R1 v R3	.727	48	.068	16.852	.000
R2 v R3	.724	48	.068	16.170	.000
Average	.764	48	.064	17.335	.000

Note: R1= stands for Rater 1; R2 = Rater 2 & R3= Rater 3

Data Analysis

Familiarity with and Interest in Science Process Skills Questionnaire

Data from the Familiarity with and Interest in Science Process Skills Questionnaire was analyzed and examined using descriptive statistics (mean values and percentages) before looking at differences among demographic sub-groups. This questionnaire gave participants three responses to choose from for each skill for familiarity: “term not familiar to me,” or “term familiar to me but not understood,” or “term familiar to me and I understand its meaning;” and for interest: “not at all interested in learning more,” or “interested in learning more,” or “very interested in learning more.” To determine the in-service elementary teachers’ familiarity with science process skills, the data was first analyzed for its mean on individual process skills. The overall familiarity with science process skills was determined by computing the mean scores. The data was then analyzed for differences among participant sub-groups (self-contained, past experience, teaches science, and teaches all subjects), using a Mann-Whitney U test the nonparametric equivalent of the independent samples t-test, and the Kruskall-Wallis test, a non-parametric test equivalent to the one-way analysis of variance (ANOVA) test.

These nonparametric tests were used because of the small sample size. The same data analysis procedure described above was used to determine teachers' interest in science process skills.

Conceptual Knowledge of Science Process Skills Test

Teachers' conceptual knowledge was examined using the Conceptual Knowledge of Science Process Skills Test, in which participants were asked to define or explain 12 science process skills stated above. Definitions or explanations of the science process skills terms were developed by the researcher by using a variety (one to ten) of other definitions found in published research. The researcher used a variety of definitions as a guide to create appropriate definitions for this research study, found on page 6 in Chapter 1. The definitions referenced were taken from four research articles (Lancour, 2004; Valentino, 2000; Longfield, 2002; Emereole, 2008), five books devoted to the science process skills (Ostlund, 1992; Funk et al., 1985; Gega & Peters, 1998; Rezba et al., 2007; Chiappetta & Koballa, 2010), and from the National Science Teacher's Association (Padilla, 1990). The definitions and explanations from these sources were then examined and elements of each definition that were common among all the definitions were highlighted to be included in the final definitions for this instrument. After determining the most common terms among the definitions, other like terms among most definitions were noted and included. Finally, the researcher determined on a case-by-case basis if any discriminate information not previously included should be incorporated into the final definition based on its perceived importance to the overall skill. The process was done in this manner to attempt to find the most comprehensive definition for each of the skills. However, such an approach has some limitations, particularly because of its subjective nature. For example, participants may provide definitions that fit with one of the definitions found in the research, but may not fit within the guidelines of the definitions created for this study. This instrument and subsequent data from it has a limitation in that the definitions created for this study were not validated by other experts in the field.

The responses were coded by matching participants response with the science process skill definitions created (see page 6 in Chapter 1): correct responses included all key terms or ideas found in the definition, with a verbatim definition not being required; partially correct responses included either one or two key terms or ideas, but not all, found in the definition or derivatives of such ideas and provided an incomplete understanding of the term; and incorrect responses did not include key terms or ideas or were unrelated or irrelevant to the skill. Correct responses received a coding point value of 3 while partially correct responses received a point value of 2, and incorrect responses received a point value of 1. After the data was coded by the researcher, another science education expert coded the data in an attempt to eliminate bias. The scores of both coders were then analyzed for inter-rater reliability and yielded a Cohen Kappa rating of .250. The data was then analyzed for differences among demographic sub-groups using both the Mann-Whitney U test and Kruskall Wallis test, as described in the data analysis for familiarity and interest.

Performance Test on Science Process Skills

Performance on science process skills was measured using scores from the Performance Test on Science Process Skills. Each item was evaluated based on the number of participants correctly answering the question using frequencies and percentages. Items that addressed the same process skill were then analyzed together, yielding percentages incorrect for the skill. This was done by calculating the overall incorrect results for all items that represented a skill. The data was then analyzed for trends among demographic sub-groups using both the Mann-Whitney U test and Kruskall Wallis test, as described in the familiarity and interest data analysis.

Relationship among Familiarity, Interest, Conceptual Knowledge and Performance

Using the data for research questions 1 to 4, each instrument was examined and compared against each of the others to determine a relationship between familiarity with, interest in, conceptual knowledge of, and performance on the science process skills. A Pearson's correlation coefficient was used to determine the relationships among these four aspects.

Summary of Data Collection

Table 4 below shows the timeline for the completion of the instrument preparation, data collection and data analysis of this research study.

Table 4

Timeline for data collection and analysis

Date	Method
February 2010	Gathering existing data collection instruments
Early March 2010	Human subjects committee request and approval
Mid-March, 2010	Adapting and modifying existing instruments for familiarity, interest, conceptual knowledge and performance on science process skills.
Late March 2010	Administered demographic form, Familiarity with and Interest in Science Process Skills Questionnaire and Conceptual Knowledge of Science Process Skills Test
Early April 2010	Administered Performance on Science Process Skills Test
Early May-June 2010	Data analysis of demographic form, Familiarity with and Interest in Science Process Skills Questionnaire
Mid May – June 2010	Data analysis of Conceptual Knowledge of Science Process Skills Test
Late May-June 2010	Data analysis of Performance on Science Process Skills Test

CHAPTER 4

RESULTS

Introduction

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 chapter presents the results from the data analysis that answers the five research questions. Included in the results are mean values and percentages for familiarity and interest ratings, conceptual knowledge, and performance test. These values are arranged based on skill, skill type, and demographic information. Also presented in the results is the comparison of the data collected from each instrument in an effort to determine if any relationship exists between familiarity, interest, conceptual knowledge, and performance on the science process skills. This chapter ends with a summary of results.

Familiarity with Science Process Skills

The results in this section were obtained via research question 1: To what extent are in-service elementary teachers familiar with science process skills? The following tables present the mean value rating for elementary teachers' familiarity with the science process skills.

Table 5

Mean Values for Familiarity with the Science Process Skills

Science Process Skill	Type of Skill	Mean Rating	Standard Deviation
Observation	Basic	2.88	0.45
Predicting	Basic	2.88	0.45
Measuring	Basic	2.83	0.48
Classification	Basic	2.75	0.53
Communicating	Basic	2.71	0.55
Inferring	Basic	2.58	0.58
Experimenting	Integrated	2.79	0.51
Hypothesizing	Integrated	2.75	0.53
Interpreting Data	Integrated	2.71	0.55
Graphing	Integrated	2.71	0.55
Identifying Variables	Integrated	2.67	0.56
Controlling Variables	Integrated	2.50	0.59
Formulating Models	Integrated	2.29	0.55

N=24

Generally, these means indicate that in-service elementary teachers were highly familiar with the science process skills. In particular, teachers reported that they were most familiar with *observation* and *predicting*, both with mean values of 2.88. Other skills with high familiarity include *measuring* (2.83) and *experimenting* (2.79). Other skills with a moderately low familiarity rating include *controlling variables* (2.50). However, the science process skill that was least familiar to teachers was *formulating models* with a mean score of 2.29.

Table 6 below shows percentage and frequency values of responses chosen by teachers on familiarity with science process skills.

Table 6

Percentages and Frequencies for Familiarity with the Science Process Skills

Term	Term not familiar to me %(frequency)	Term familiar to me but not understood %(frequency)	Term familiar to me and I understand its meaning %(frequency)
Observation	4.2 (1)	4.2 (1)	91.7 (22)
Classification	4.2 (1)	16.7 (4)	79.2 (19)
Measuring	4.2 (1)	8.3 (2)	87.5 (21)
Inferring	4.2 (1)	33.3 (8)	62.5 (15)
Predicting	4.2 (1)	4.2 (1)	91.7 (22)
Communicating	4.2 (1)	20.8 (5)	75.0 (18)
Hypothesizing	4.2 (1)	16.7 (4)	79.2 (19)
Experimenting	4.2 (1)	12.5 (3)	83.3 (20)
Identifying Variables	4.2 (1)	25.0 (6)	70.8 (17)
Formulating Models	4.2 (1)	62.5 (15)	33.3 (8)
Interpreting Data	4.2 (1)	20.8 (5)	75.0 (18)
Controlling Variables	4.2 (1)	41.7 (10)	54.2 (13)
Graphing	4.2 (1)	20.8 (5)	75.0 (18)
Total	4.2 (13)	22.1 (69)	73.7 (230)

N=24

Teachers overwhelmingly reported that they were both familiar and understood the science process skills (73.7%). Twenty two teachers reported that they were familiar with and understood the meaning of *observation*, *predicting*, and 21 teachers stated that they were familiar and understood what *measuring* is. Likewise, teachers reported that they were ‘familiar with but did not understand the meaning’ of *formulating models* (62.5%) and *controlling variables* (41.7%) more than any other skill. There was no difference in frequency between skills in the ‘term not familiar to me’ rating.

A Mann-Whitney test was performed to find out if there were significant differences between teachers’ familiarity ratings of basic and integrated skills. The results have been presented in Table 7 below.

Table 7

Comparison of Familiarity between the Basic and Integrated Process Skills

Type of Skill	N	Mean (72)	Standard Deviation	Mean Rank	Sum of Ranks	*U*	*W*	*Z*	*sig.*
Basic	6	66.5	2.74	8.92	53.5	9.5	37.5	-1.657	.101
Integrated	7	63.1	4.22	5.36	37.5				

*Significant at p<.05

As shown in Table 7 a Mann-Whitney U test revealed that there was no significant difference (*U* = 9.5, *p* > .05) between teachers' familiarity ratings of the basic and integrated 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 utilized both Mann-Whitney U and Kruskal-Wallis tests to compare certain demographic variables to overall scores on familiarity. As shown in Tables 8 and 9, both tests revealed no significant differences in familiarity ratings between the demographic variables. These results suggest the homogeneity of this group.

Table 8

Comparison of Familiarity between the Demographic Variables

Demographic		N	Mean Rank	Sum of Ranks	*U*	*W*	*Z*	*sig.*
Self-Contained Classroom	Yes	12	11.58	139	61	139	-.649	.551
	No	12	13.42	161				
Teaches Science	Yes	12	14.67	176	46	124	-1.534	.143
	No	12	10.33	124				
Teaches Core Subjects	Yes	7	13.14	92	55	208	-.292	.804
	No	17	12.24	208				
Past Experience in Another Grade Level	Yes	14	13.61	190.5	54.5	109.5	-.927	.371
	No	10	10.95	109.5				

N=24

Table 9

Comparison of Familiarity among the Demographic Variables

Demographic		N	Mean Rank	x^2	*df*	*sig.*
Age	24-30 years	5	12.2	3.24	4	.519
	31-35 years	6	13.75			
	36-40 years	3	11.33			
	41-45 years	5	8.50			
	46+ years	5	16.00			
Experience	1-5 years	7	10.14	2.554	2	.279
	6-10 years	6	16.17			
	11+ years	11	12.00			
Grade Taught	K-2	3	11.17	.226	2	.875
	3rd-5th	11	13.23			
	6th-8th	10	12.10			
Number of college science course taken	3-6 courses	2	14.50	1.787	3	.618
	7-9 courses	12	12.04			
	10-12 courses	6	10.42			
	13+ courses	4	16.00			

N=24

Interest in Science Process Skills

The extent of the teachers' interest in science process skills was determined through research question 2: To what extent are in-service elementary teachers interested in science process skills? Table 10 presents the mean value rating for elementary teachers' interest in the science process skills.

Table 10

Mean Values for Interest in the Science Process Skills

Science Process Skill	Type of Skill	Mean Rating	Standard Deviation
Communicating	Basic	2.29	0.62
Predicting	Basic	2.17	0.64
Inferring	Basic	2.13	0.61
Observation	Basic	2.08	0.65
Classification	Basic	2.08	0.65
Measuring	Basic	2.08	0.65
Experimenting	Integrated	2.42	0.58
Controlling Variables	Integrated	2.39	0.58
Formulating Models	Integrated	2.38	0.65
Interpreting Data	Integrated	2.33	0.56
Identifying Variables	Integrated	2.29	0.55
Hypothesizing	Integrated	2.25	0.61
Graphing	Integrated	2.13	0.61

N=24

Overall, the results indicate that elementary teachers were moderately interested in learning more about the science process skills. Teachers were most interested in learning more about *experimenting* (2.42), *controlling variables* (2.39), and *formulating models* (2.38), all of which are integrated process skills. These results are somewhat consistent with results presented in Table 3 above indicating that teachers were least familiar with *controlling variables* and *formulating models.* In contrast to results presented in Table 10 above, teachers report being most familiar with *experimenting,* as shown in Table 5. Mean values also indicate that teachers were least interested in learning more about *observation* (2.08), *classification* (2.08), *measuring* (2.08), and *graphing* (2.13), the first three of which are basic process skills. This is also consistent with reported familiarity, as teachers reported being most familiar with *observation* and *measuring.*

Table 11 below reports the percentage and frequencies of teachers' interest ratings. Responses varied, however, were fairly consistent. Overall, teachers are somewhat interested in learning more about the science process skills (56.9 %), a promising result.

Table 11

Percentages and Frequencies for Interest in the Science Process Skills

Science Process Skill	Not at all interested in learning more %(frequency)	Interested in learning more %(frequency)	Very interested in learning more %(frequency)
Observation	16.7 (4)	58.3 (14)	25.0 (6)
Classification	16.7 (4)	58.3 (14)	25.0 (6)
Measuring	16.7 (4)	58.3 (14)	25.0 (6)
Inferring	12.5 (3)	62.5 (15)	25.0 (6)
Predicting	12.5 (3)	58.3 (14)	29.2 (7)
Communicating	8.3 (2)	54.2 (13)	37.5 (9)
Hypothesizing	8.3 (2)	58.3 (14)	33.3 (8)
Experimenting	4.2 (1)	50.0 (12)	45.8 (11)
Identifying Variables	4.2 (1)	62.5 (15)	33.3 (8)
Formulating Models	8.3 (2)	45.8 (11)	45.8 (11)
Interpreting Data	4.2 (1)	58.3 (14)	37.5 (9)
Controlling Variables*	4.2 (1)	50.0 (12)	41.7 (10)
Graphing	12.5 (3)	62.5 (15)	25.0 (6)
Total	10.0 (31)	56.9 (177)	33.1 (103)

N=24, *N=23

The difference of means between the basic process skills and the integrated process skills was examined using a Mann-Whitney U test. The results shown in Table 12 below, show a significant difference (U = 4.5, p < .05) between teachers' interest in basic and integrated process skills. Teachers indicated a significantly higher interest in learning more about the integrated process skills than basic process skills overall. This result may be because they are not as comfortable with the integrated process skills as the basic process skills, although the results from the familiarity portion do not support this.

Table 12

Comparison of Interest between the Basic and Integrated Process Skills

Type of Skill	N	Mean (72)	Standard Deviation	Mean Rank	Sum of Ranks	*U*	*W*	*Z*	*sig.*
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				

Table 13 shows that there was a significant difference (U =26.5, $p < .05$) between teachers with past teaching experience in another grade level than those who did not have past teaching experience at that grade level.

Table 13

Comparison of Interest between the Demographic Variables

Demographic		N	Mean Rank	Sum of Ranks	*U*	*W*	*Z*	*sig.*
Self-Contained Classroom	Yes	12	11.79	141.5	63.5	141.5	-.502	.630
	No	12	13.21	158.5				
Teaches Science	Yes	12	13.79	134.5	56.5	134.5	-.915	.378
	No	12	11.21	165.5				
Teaches Core Subjects	Yes	7	10.57	74	46	74	-.876	.418
	No	17	13.29	226				
Past Experience in Another Grade Level	Yes	14	15.61	218.5	26.5	81.5	-2.604	.009
	No	10	8.15	81.5				

N=24

As shown in Table 14 below, Kruskal Wallis tests to compare certain demographic variables to overall scores on interest showed there were no significant differences in interest ratings on all of demographic variables. These results suggest the homogenous nature of this group.

Table 14

Comparison of Interest among the Demographic Variables

Demographic		N	Mean Rank	x^2	*df*	*sig.*
Age	24-30 years	5	11.90	.874	4	.928
	31-35 years	6	13.08			
	36-40 years	3	13.83			
	41-45 years	5	10.30			
	46+ years	5	13.80			
Experience	1-5 years	7	10.50	.826	2	.662
	6-10 years	6	13.33			
	11+ years	11	13.32			
Grade Taught	K-2	3	11.67	.209	2	.901
	3rd-5th	11	12.05			
	6th-8th	10	13.25			
Number of college science course taken	3-6 courses	2	12.25	.012	3	1.00
	7-9 courses	12	12.63			
	10-12 courses	6	12.50			
	13+ courses	4	12.25			

N=24

Conceptual Knowledge of Science Process Skills

The conceptual knowledge of science process skills among the teachers was elicited in research question 3: What is the in-service elementary teachers' conceptual knowledge of science process skills? Table 15 below presents the mean value scores for elementary teacher conceptual knowledge of science process skills.

Table 15

Mean Scores on Conceptual Knowledge of Science Process Skills

Science Process Skill	Type of Skill	Mean Score	Standard Deviation
Classify	Basic	2.25	0.79
Predict	Basic	2.13	0.54
Communication	Basic	2.00	0.51
Observe	Basic	1.92	0.72
Infer	Basic	1.67	0.87
Measure	Basic	1.29	0.44
Experiment	Integrated	2.29	0.81
Variables	Integrated	2.25	0.53
Interpret Data	Integrated	1.96	0.91
Model	Integrated	1.63	0.82
Graphing	Integrated	1.63	0.71
Hypothesize	Integrated	1.38	0.58

N=24

Table 15 indicates that teachers possessed a moderate to low conceptual knowledge of science process skills. The science process skill in which teachers possessed the highest conceptual knowledge is *experiment* (2.29). Teachers provided quality statements in defining *experiment*, using terms that indicated key factors of the definition such as “procedures” “test a hypothesis” and “using [other process skills]”. Statements such as *“testing a problem using a standardized method-use a control and variables”* (Teacher 15) and *“to test an idea to see if it is valid using observations, tasks, and data”* (Teacher 19) yielded a scoring of *correct* (3). Other skills in which teachers demonstrated a higher conceptual knowledge were *classify* (2.25) and *variables* (2.25).

The skills in which teachers possessed the lowest conceptual knowledge are *measure* (1.29) and *hypothesize* (1.38). These results are interesting since teachers report *measure* as being one skill in which they are most familiar with. For example, in defining the term *measure* teachers provided the following definitions: *“define the amount of* *something, show change over time"* (Teacher 13), *"giving a scale of weight, length, volume, etc. to something for further statistics"* (Teacher 23), and *"to determine the amount"* (Teacher 24). Teacher definitions focused on terms associated with measuring, such as weight, length, and volume, but failed to explain what these vocabulary actually mean and how they fit within the terms of measure. Few teachers used words such as "quantity" or "standard," key features of the definition of *measure.* One teacher (Teacher 14) used the word "measurement" in the definition itself. In defining *hypothesize*, most teacher responses (12 out of 24) included the terms "guess" or "educated guess" Only one teacher made mention of a "relationship," specifically stating *"to predict possible outcomes based on cause and effect"* (Teacher 5). From these statements, one can tell that these elementary teachers use everyday language in describing the skills and do not use, or very infrequently use scientific language. The definitions that were referenced in scoring teacher responses can be found in Chapter 1 on page 6. A full listing of teacher responses has been provided as appendix E.

Percent and frequency of scores on each skill is presented in Table 16 below. The frequency supports mean values. For example, no teacher correctly defined the skill *measure,* contributing to the low conceptual knowledge score. Likewise, only one teacher correctly defined the skill *hypothesize.* Overall scores indicate that teachers did not have a good conceptual knowledge of the science process skills (36.8%), or have limited conceptual knowledge of the science process skills (39.9%).

Table 16

Percentages and Frequencies for Conceptual Knowledge Correctness of Science Process Skills

Science Process Skill	Incorrect %(frequency)	Partially Correct %(frequency)	Correct %(frequency)
Observe	29.2 (7)	50.0 (12)	20.8 (5)
Classify	20.8 (5)	33.3 (8)	45.8 (11)
Measure	70.8 (17)	29.2 (7)	0.0 (0)
Infer	58.3 (14)	16.7 (4)	25.0 (6)
Predict	8.3 (2)	70.8 (17)	20.8 (5)
Communication	12.5 (3)	75.0 (18)	12.5 (3)
Hypothesize	66.7 (16)	29.2 (7)	4.2 (1)
Experiment	20.8 (5)	29.2 (7)	50.0 (12)
Variable	4.2 (1)	66.7 (16)	29.2 (7)
Model	58.3 (14)	20.8 (5)	20.8 (5)
Interpret Data	41.7 (10)	20.8 (5)	37.5 (9)
Graphing	50.0 (12)	37.5 (9)	12.5 (3)
Total	36.8 (106)	39.9 (115)	23.3 (67)

N=24

Descriptive statistics showed that the skills in which teachers had high conceptual knowledge included both basic and integrated process skills, as did the skills in which teachers had low conceptual knowledge. Therefore, a Mann-Whitney U test was conducted to compare scores of conceptual knowledge between the basic and integrated process skills. As shown in Table 17, a Mann-Whitney U test revealed no significant difference in conceptual knowledge between the basic and integrated process skills.

Table 17

Comparison of Conceptual Knowledge between the Basic and Integrated Process Skills

Type of Skill	N	Mean (72)	Standard Deviation	Mean Rank	Sum of Ranks	*U*	*W*	*Z*	*sig.*
Basic	6	45	8.34	6.42	38.5	17.5	38.5	-.080	.937
Integrated	6	44.5	8.94	6.58	39.5				

Further testing used Whitney-Mann U and Kruskal-Wallis tests to compare scores based on demographic data. Table 18 shows that there were no significant differences between demographics and conceptual knowledge.

Table 18

Comparison of Conceptual Knowledge between the Demographic Variables

Demographic		N	Mean Rank	Sum of Ranks	*U*	*W*	*Z*	*sig.*
Self-Contained Classroom	Yes	12	14.38	172.5	49.5	127.5	-1.308	.198
	No	12	10.63	127.5				
Teaches Science	Yes	12	11.96	143.5	65.5	143.5	-.378	.713
	No	12	13.04	156.5				
Teaches Core Subjects	Yes	7	13.50	94.5	52.5	205.5	-.448	.664
	No	17	12.09	205.5				
Past Experience in Another Grade Level	Yes	14	14.11	197.5	47.5	102.5	-1.326	.192
	No	10	10.25	102.5				

N=24

Similarly, Table 19 shows that Kruskal-Wallis tests revealed there were no significant differences between demographics and conceptual knowledge

Table 19

Comparison of Conceptual Knowledge among the Demographic Variables

Demographic		N	Mean Rank	x^2	*df*	*sig.*
Age	24-30 years	5	12.20	5.770	4	.217
	31-35 years	6	9.75			
	36-40 years	3	12.17			
	41-45 years	5	18.90			
	46+ years	5	9.90			
Experience	1-5 years	7	12.50	.294	2	.863
	6-10 years	6	11.25			
	11+ years	11	13.18			
Grade Taught	K-2	3	10.00	1.497	2	.473
	3rd-5th	11	14.36			
	6th-8th	10	11.20			
Number of college science course taken	3-6 courses	2	12.00	2.040	3	.564
	7-9 courses	12	10.92			
	10-12 courses	6	13.08			
	13+ courses	4	16.63			

N=24

Performance on Science Process Skills

The in-service elementary teachers' performance was elicited via the research question 4: How well do in-service elementary teachers perform on science process skills? The percentage of correct responses for each science process skill demonstrates the overall teacher performance on the skills and is presented in Table 20.

Table 20

Percentages of Correct Responses on Performance Test

Item Number on Performance Test	Number of Items	Science Process Skill	Type of Skill	Correct Responses (%)
15, 22, 40	3	Classification	Basic	98.7
14, 27, 34	3	Predicting	Basic	97.3
1, 35, 39	3	Inferring	Basic	96
25, 26, 44, 48	4	Measuring	Basic	90
21, 37, 45	3	Communicating	Basic	86.7
9, 46, 47	3	Observation	Basic	82.7
12, 29, 36	3	Interpreting Data	Integrated	98.7
3, 11, 13, 42	4	Experimenting	Integrated	98
2, 5, 17, 30, 41	5	Hypothesizing	Integrated	94.4
10, 28	2	Formulating Models	Integrated	94
7, 8, 19, 20, 32, 33, 38	7	Identifying Variables	Integrated	88
6, 18, 23, 31	4	Controlling Variables	Integrated	82
4, 16, 24, 43	4	Graphing	Integrated	81

Overall, teachers performed well with individual scores ranging from 81.25% to 97.92%. For example, teachers performed well on the skills of *classification* (98.7), *interpreting data* (98.7), and *experimenting* (98.0). These results are also interesting. Teachers are consistent in that they report being most familiar with the skill *experiment, but* report *inferring* as one of the skills they are least familiar with.

The skill in which teachers performed the most poorly was *graphing,* with 19% of all responses being incorrect. Teachers also performed poorly on *observation* and *controlling variables.* This again is an interesting result, as teachers report *observation* as being one skill that they are most familiar with. However, teachers do report *controlling variables* as being one skill in which they are the least familiar which is consistent with their performance. Teachers also report *graphing* as a skill that they are least interested in learning more about and yet they performed the most poorly on it.

Table 21 reports the individual test items and the frequency and percentage of incorrect responses on those test items.

Table 21

Percentages and Frequencies for Incorrect Responses on the Performance Test

Item Number on Performance Test*	Number of items	Science Process Skills Tested	Incorrect Responses %(frequency)
1, 5, 9, 11, 12, 16, 22, 26, 29, 30, 34, 37, 39, 40, 42, 44	16	Classification, Communicating, Experimenting, Graphing, Hypothesizing, Inferring, Interpreting Data, Measuring Observation, Predicting	0% (0)
3, 10, 13, 14, 15, 17, 25, 27, 32, 36, 41	11	Classification, Experimenting, Formulating Models, Hypothesizing, Identifying variables, Interpreting Data, Measuring, Predicting	4% (1)
7, 28, 45	3	Identifying variables, Formulating Models, Communicating	8% (2)
8, 18, 19, 31, 33, 35, 38, 43	8	Controlling variables, Graphing, Identifying variables, Inferring	12% (3)
23	1	Controlling variables	16% (4)
2, 24, 46	3	Hypothesizing, Graphing, Observation	20% (5)
20	1	Identifying Variables	24% (6)
6, 21	2	Controlling Variables, Communicating	32% (8)
47, 48	2	Observation, Measuring	36% (9)
4	1	Graphing	44% (11)

*See Table 20 for item numbers arranged by skill

Teachers performed most poorly on Question #4, a question on graphing, in which eleven of the twenty-four teachers answered incorrectly (44%). This question provided teachers with a set of data and asked them to select the correct graph, given as four multiple choice responses, which represented the given data (see Appendix C). This group of teachers also performed poorly on question 47, an item related to the skill *observation,* in which participants were asked to identify which one of the four pictures is different from the other three (see appendix C). Question 48 was linked to the skill of *measuring* and asked participants to estimate the height of a tree using a presented smaller tree as a reference. Teachers also performed poorly on this question, with 36% of teachers answering it incorrectly. Despite the poor performance on several of the items, sixteen of the forty-eight questions (33.3%) were answered correctly by all twenty-four teachers. These questions addressed ten of the thirteen skills. For example, question 40 asked participants how they would arrange the given seashells (drawing), focusing on the skill of *classifying*. Questions 11 and 42 both deal with the skill of *experimenting* and ask participants how they would set up an experiment for a given situation, such as the relationship between air pressure and the bounce of a basketball (Question 11) or testing which plant food is the best (Question 42). Overall, teachers performed well on this test, demonstrating some competence in the science process skills. Further testing using Whitney-Mann U test revealed there were no significant differences between demographics and performance as reported in Table 22 below.

Table 22

Comparison of Performance between the Demographic Variables

Demographic		N	Mean Rank	Sum of Ranks	*U*	*W*	*Z*	*sig.*
Self-Contained Classroom	Yes	12	14.54	174.5	47.5	125.5	-1.436	.160
	No	12	10.46	125.5				
Teaches Science	Yes	12	11.83	142.0	64.0	142.0	-.469	.671
	No	12	13.17	158.0				
Teaches Core Subjects	Yes	7	12.14	85.0	57.0	85.0	-.161	.901
	No	17	12.65	215.0				
Past Experience in Another Grade Level	Yes	14	12.57	176.0	69.	124.	-.059	.977
	No	10	12.40	124.0				

N=24

Similarly, Table 23 shows that Kruskal-Wallis tests revealed there were no significant differences between demographics and performance.

Table 23

Comparison of Performance among Demographic Variables

Demographic		N	Mean Rank	x^2	*df*	*sig.*
Age	24-30 years	5	13.00	2.943	4	.567
	31-35 years	6	11.25			
	36-40 years	3	7.67			
	41-45 years	5	16.00			
	46+ years	5	12.90			
Experience	1-5 years	7	11.07	.802	2	.670
	6-10 years	6	11.67			
	11+ years	11	13.86			
Grade Taught	K-2	3	12.33	.057	2	.972
	3rd-5th	11	12.86			
	6th-8th	10	12.15			
Number of college science course taken	3-6 courses	2	12.00	2.165	3	.539
	7-9 courses	12	10.67			
	10-12 courses	6	15.67			
	13+ courses	4	13.50			

N=24

Relationship among Familiarity, Interest, Conceptual Knowledge and Performance

The extent of the relationship among familiarity, interest, conceptual knowledge and performance on science process skills was determined in research question 5: To what extent are in-service elementary teachers' familiarity, interest, conceptual knowledge and performance on science process skills related to each other? Table 24 presents the Pearson correlation coefficient values of the nature of the relationships among the four aspects (Familiarity, Interest, Conceptual Knowledge and Performance)

Table 24

Pearson Correlation Coefficient between Science Process Questionnaires and Tests

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

*Significant at the 0.01 level

The results presented in Table 24 show that there is a significant relationship (*r* (22) = .002, $p < .01$) between familiarity and interest in the science process skills. This relationship is to be expected, as they both measure teacher self-reported opinions. While 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. This negative relationship indicates that the more familiar teachers claim to be with the process skills, their conceptual knowledge and performance on these skills goes down and likewise with interest and conceptual knowledge. A possible reason for these negative relationships could be that familiarity and interest are opinions and conceptual knowledge and performance are cognitive aspects that require the teachers to think and solve a problem. Further, teachers' performance on science process skills tasks require use of conceptual knowledge and the two have a positive relationship though it is insignificant. This implies that even if teachers are more familiar with science process skills, their poor conceptual knowledge on the science process skills may affect their performance.

Summary of Major Findings

This group of in-service elementary teachers reports a high level of familiarity with the science process skill, both basic and integrated skills, and a moderate interest in learning more about the process skills. Teachers were most interested in learning more about *experimenting*, *controlling variables*, and *formulating models*, all of which are integrated process skills. This finding is consistent with results on familiarity, in that teachers were least familiar with *controlling variables* and *formulating models.* This makes sense, as teachers would be interested in learning more about the skills they are not familiar with. Likewise, these teachers were least interested in learning more about the basic skills of *observation, classification, measuring*, and rate being highly familiar with these skills. Teachers would be least interested in learning about skills they are very familiar with. In contrast, teachers reported having a high level of familiarity with, and more interest in, *experimenting.* Teachers may not be comfortable with integrated process skills and therefore they were interested in learning more about these skills despite their high level of familiarity with them. Elementary teachers are more likely to teach the basic process skills because of the age and grade levels at which they teach. Teaching the basic process skills helps them to become more familiar with these skills, and teachers would naturally be more interested in learning more about the integrated skills because of the possible lack of interaction with them in their own classrooms.

In examining conceptual knowledge, teachers overall performed poorly on all skills. Although 73.7% of teachers reported that they were familiar with and understood the science process skills, 76.7% of teachers had a poor or incomplete knowledge of the process skills. In particular, teachers possessed the lowest conceptual knowledge on *measure*, despite *measure* being one skill in which they are most familiar with and least interested in learning more about. Teachers held the highest conceptual knowledge on *experiment*. This is a consistent result with the high familiarity and interest rating teachers gave this skill.

Overall, teachers performed well on the science process skill, doing particularly well on *classification*, *interpreting data*, and *experimenting*. The skills on which teachers performed most poorly were *graphing*, *observation* and *controlling variables.* The poor performance on *graphing* should be noted, as teachers also reported they were very interested in learning more about this skill. Likewise, *observation* is a skill these teachers reported as being most familiar with and less interested in learning more about it, yet the teachers performed poorly on it. Consistent with their performance, teachers reported *controlling variables* as being one skill in which they were the least familiar.

Of particular interest in these results is the skill *experimenting.* Teachers had a high familiarity with, interest in, conceptual knowledge, and performance on *experimenting*. A possible explanation for this is that these teachers explicitly teach this skill more than the others to their students, increasing their familiarity with, conceptual knowledge, and performance on this skill. Because they frequently teach this skill, they are likely to be more interested in learning more about it as well.

A comparison of how teachers rated and performed on the skills on each instrument is presented in Table 25 below.

Table 25

Comparison of Ratings/Performance on Science Process Skills by Construct

Rating/ Performance	Familiarity	Interest	Conceptual Knowledge	Performance
High	Observation	Experimenting	Experiment	Classification
↑	Predicting	Controlling Variable	Classify	Interpreting Data
	Measuring	Formulating Models	Variables	Experimenting
	Experimenting	Interpreting Data	Predict	Predicting
	Hypothesizing	Identifying Variables	Communication	Inferring
	Classifying	Communicating	Interpret Data	Hypothesizing
	Communicating	Hypothesizing	-	Formulating Models
	Interpreting Data	Predicting	Observe	Measuring
	Graphing	Inferring	Infer	Identifying Variables
	Identifying Variables	Graphing	Model	Communicating
	Inferring	Observation	Graphing	Observation
↓	Controlling Variables	Classification	Hypothesize	Controlling Variables
Low	Formulating models	Measuring	Measuring	Graphing

CHAPTER 5

DISCUSSION AND CONCLUSIONS

Introduction

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 chapter presents a discussion of the results of this study and how these results relate to previous work and add to existing research on science process skills. A summary of major findings and how those findings relate to previous research has been presented. Limitations and implications of the findings are also discussed, followed by recommendations for future research in the area of science process skills. Finally, the chapter ends with a conclusion section in which major findings of this study have been presented.

Discussion

In general, in-service elementary teachers in this study reported a high familiarity with both basic and integrated science process skills. Teachers were not as interested in learning more about the process skills as they were familiar with them. As such, there is a gulf between their levels of familiarity and interest in learning more about science process skills. However, to a certain extent this group of teachers was significantly more interested in learning about the integrated process skills than the basic process skills. As stated in chapter 4, teachers may not be comfortable with integrated process skills and therefore they were interested in learning more about these skills despite their high level of familiarity with them. Elementary teachers are more likely to teach the basic process skills because of the age and grade levels at which they teach. Teaching the basic process skills helps them to become more familiar with these skills, and teachers would naturally be more interested in learning more about the integrated skills because of the possible lack of interaction with them in their own classrooms.

While the results show that teachers were not interested in learning more about science process skills with which they were most familiar with, this also implies that these teachers may not teach them because of their low interest. Research shows that teachers don’t teach what they don’t know or what they are not interested in (Bhattacharyya et al., 2009). Research also shows that teachers’ attitude towards science or certain topics has an effect on the extent to which they teach science or certain topics (Downing et al., 1997).

The results of this study also indicate that teachers are least interested in basic process skills such as *measuring, classification,* and *observation.* Teachers who do not teach these basic science process skills are setting students up for poor science achievement because such skills are part of the basic elements for better understanding of science content knowledge and for using the integrated process skills in science activities. Further, teachers that are least familiar with the integrated process skills may also avoid teaching them because of their own low familiarity with them. On a positive note, the teachers rated the science process skills they were least familiar with as the ones they were most interested in learning more about. This offers some hope in that this group of teachers is open to addressing deficiencies in their familiarity and conceptual knowledge of the science process skills. More research should be done in this area, particularly examining the relationship between familiarity and interest and how these translate into classroom practice.

Science process skills are of the utmost necessity for doing inquiry (Settlage & Southerland, 2007), science achievement (Brotherton & Preece, 1996), understanding of the nature of science (Padilla, 1991), and for 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. This group of teachers demonstrated a poor conceptual knowledge of the science process skills, with 76.7% of all responses on the conceptual knowledge test being incorrect or only partially correct. This finding is consistent with those reported in previous studies. For example, Emereole (2008) found that teachers reported they were highly familiar with the science process skills, but that their conceptual knowledge was very poor. Similarly, Farsakoglu et al. (2008) found that teachers could not adequately define the science process skills, consistent with the findings from the conceptual knowledge test in this study.

The poor conceptual knowledge held by these teachers should be a call to action on the part of science teacher education and professional development programs. Prior 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 and as such may not be using it in their classrooms (Anderson, 2002). Such teachers also may not be promoting a positive attitude towards science among students in their classrooms (Downing et al., 1997) because of their poor conceptual knowledge. Future research in this area should also examine the relationship between conceptual knowledge of the process skills and how that translates into classroom instruction and use of the science process skills.

If science teacher educators continue to ignore this aspect of conceptual knowledge they will continue to send teachers into the field who are poorly prepared to teach science and science process skills. Likewise, science teacher educators cannot expect teachers who have a poor conceptual knowledge of science process skills to teach science by inquiry, an aspect that is not in line with science education reforms. 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 process skills. Integrating science process skills instruction with instruction on inquiry will ensure that elementary teachers are prepared to effectively teach science.

Teachers performed well, overall, on the performance on science process skills test, contrasting the results of conceptual knowledge 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. Multiple choice questions also allow teachers a greater chance at guessing the right answer. However, more research should be done to examine this claim. Prior studies have focused on performance of the process skills under the assumption that proficiency on performance translates into effective process skill teaching and understanding. However, the results of the present study indicate that these teachers do not possess an acceptable level of conceptual knowledge on the science process skills despite performing well on the skills.

The teachers performed equally well on both basic and integrated skills. These results offer some hope that teachers may teach the science process skills because they performed well on them, but only within given contexts. The fact that teachers performed well on context-based science process skills items and poorly on conceptual knowledge leads to the idea 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. Implicit instructional approach prevents the opportunity for students and teachers alike to gain a deeper understanding of the content and skills. Implicit instructional approach also prevents the opportunity for science process skills to have 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, as is to be expected because they both measure teacher self-reported opinions. These results may be due to the small sample size. However, it is still interesting to note that the skills in which teachers reported being familiar with were the skills in which teachers performed most poorly on the performance tests. For example, these teachers rated *observation* as the skill they were most familiar with and it was one skill in which they performed the worst on. These results mimic the correlation results that indicated familiarity and performance had a negative correlation. This is an important finding, as 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 items in the test.

One of the major outcomes of this study was the teachers' rating and performance on the skill of *experimenting.* This 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 others to their students, increasing their familiarity with, conceptual knowledge, and performance on this skill. Because they frequently teach this skill, they are likely to be more interested in learning more about it as well.

Looking more specifically at individual skills, these teachers had a poor 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, & Bowen (1998) reported that pre-service teachers have graphing difficulties and such difficulties were attributed to a lack of appropriate training in the graphing skills. Teachers also performed poorly on the skill *measuring.* 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. Interestingly, these two skills (graphing and measuring) are the most identifiable as math skills. Even though the elementary teachers in this study were in a graduate degree program for math and science, their training did not seem to translate well onto the cognitive tasks, indicated by their poor conceptual knowledge and poor performance on science process skills that were emphasized in their science courses of the graduate program. The poor performance on these skills should inform teacher preparation programs of deficiencies among elementary education teachers in science processes that are essential for inquiry science teaching and learning. Because these skills are important for both math and science, teacher programs should emphasize the relationship of math and science skills and emphasize these skills in both types of courses. Future research should examine the relationship and impact between performance on math skills and performance on science skills.

Limitations

This research was limited in that it examined a small, relatively homogenous sample of in-service elementary education teachers. The research is also limited by the instruments. The conceptual knowledge instrument was found to be reliable; however, inter-rater reliability was low possibly because of the lack of a standard rubric by which each rater could follow for rating. The performance test had a low reliability rating. Although this could be attributed to the small sample and the high variance among skills being rated, this instrument should continue to be revised until a higher reliability is reached. Other instruments that are available tend to focus on either the basic or integrated process skills, thereby necessitating the use and subsequent manipulation of this comprehensive performance test.

Recommendations

Future research should extend this study to a greater pool of participants, including pre-service teachers, in-service secondary teachers, and students. In-service secondary teachers should particularly be examined because they are also expected to teach the science process skills and inquiry. Although previous research has examined in-service teachers (Emereole, 2008), it was not as holistic as this one, only examining familiarity and conceptual knowledge. Also, Emereole’s (2008) study was conducted in Botswana, limiting his results to that area. An understanding of student science process skill familiarity, interest, conceptual knowledge, and performance will allow for research to compare students and teachers to better determine the extent of influence teachers have on their students in the process skills. Extension of this research may also find more significant relationships between cognitive and non-cognitive elements on science process skills in a larger and more diverse sample. Any future research using the instruments used herein should attempt to increase the reliability value of the performance on science process skills test. Future research should look into extending this study using a mixed method approach, by collecting both quantitative and qualitative data. Qualitative data should include in-class observations, science lesson activity analysis, and interviews.

Teacher education programs, in the meantime, 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 one integrated skill misses the opportunity to provide a rich and complete understanding of science among students and teachers.

Future research should focus more on the element of conceptual knowledge. Teachers are often confronted with instances in which they must define or rationalize a concept without a textbook or reference material present. As such, teachers with low conceptual knowledge on the science process skills may not effectively convey the true definitions, meanings, and understanding of the concepts and skills to their students.

More research should be done in this area, focusing on how conceptual knowledge of teachers effects their students' conceptual knowledge and performance. Other research may focus on why these teachers perform well on a performance test but still have low conceptual knowledge, possibly examining the influence of context. Follow-up interviews could determine why teachers think this disconnect exists, assisting researchers in understanding such a gap.

Research should also examine the attitudes of both pre- and in-service teachers towards the process skills. The relationship between attitude towards science and the science process skills has been studied (Downing et al., 1997), but specific attitudes towards the skills themselves have not. Researching this construct is important to understanding overall teacher interaction with the process skills. Attitude can have a significant impact on what teachers teach and how they teach it, both positively and negatively. The examination of attitude should include how teachers' attitude towards science not only relates to their classroom practice but how it relates to teacher familiarity, interest, conceptual knowledge, and performance as studied here.

A push for more investigation in the science process skills is necessary. Most of the research studies on the science process skills in the US were completed over a decade ago with many being done over 30 years ago. Although they are still relevant, they need to be revisited because the field of science education has changed drastically since then. Theories, ideas, and methods central to science education have all changed, therefore the influence and relationships that these science process skills have on these new philosophies should be explored.

Conclusions

This group of in-service elementary teachers reported a high level of familiarity with the science process skills, both basic and integrated, and a moderate interest in learning more about the process skills. Teachers were mostly interested in learning more about integrated process skills. This finding is consistent with results on familiarity, in that teachers were least familiar with *controlling variables* and *formulating models,* both integrated process skills. Likewise, these teachers were least interested in learning more about the basic skills, consistent with reporting they were highly familiar with these skills. Teachers performed poorly on all skills in the conceptual knowledge realm, in contradiction to their high familiarity rating. Overall, teachers performed well on the science process skill performance test. In comparing data from each instrument for relationships, familiarity and interest were found to be significantly correlated and no other significant relationships were found. Although other significant relationships did not exist, negative relationships were found between familiarity and conceptual knowledge, familiarity and performance, and interest and conceptual knowledge.

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APPENDICES

APPENDIX A
QUESTIONNAIRE ON SCIENCE PROCESS SKILLS

Dear Participant,
This questionnaire has been designed to evaluate teacher's understanding of science process skills. There are no right or wrong answers and your scores will in no way be associated with you or any grade for any course in which you are enrolled. The information you provide is voluntary.

DEMOGRAPHIC INFORMATION:

Name:____________________________ **Gender**: M F **Age**:__________

Teaching Experience (include the current year):________________________________

Grade level you teach:_____________________ **Check here if self-contained**: ☐

Subjects you teach (check all that apply):

- ☐ Science
- ☐ Math
- ☐ Social Science/Social studies
- ☐ Language Arts
- ☐ All (Science, math, language arts, social studies)
- ☐ Special Education
- ☐ Other (please specify):___________

Have you taught other subjects and/or grade levels in the past?

Past grade level:_________Subject:__________________________________Years:________

Past grade level:_________Subject:__________________________________Years:________

Number of college science courses you have taken:

- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3-4
- ☐ 5-6
- ☐ 7-9
- ☐ 10-12
- ☐ 13-15
- ☐ More than 15

Your undergraduate degree was in:

- ☐ Elementary education
- ☐ Special Education
- ☐ Other:____________________________

What endorsements do you hold on your teaching certificate?

- ☐ Science
- ☐ Math
- ☐ Social Studies
- ☐ Language Arts
- ☐ Special Education
- ☐ Early Childhood
- ☐ Middle School
- ☐ LBS
- ☐ Other:_____

Section 1: Identifying science process skills

We want to know if the following terms are familiar to you and to what extent you think they are interesting. The table has **two** parts - In part 'A' please mark if the term is familiar to you and understandable; in part 'B' please mark to what extent you are interested in learning more information on the term.

Part A: Familiarity

	The term	Term not familiar to me	Term familiar to me but not understood	Term familiar to me and I understand its meaning
1	Observation			
2	Classification			
3	Measuring			
4	Inferring			
5	Hypothesizing			
6	Experimenting			
7	Identifying Variables			
8	Formulating Models			
9	Interpreting Data			
10	Predicting			
11	Controlling Variables			
12	Graphing			
13	Communication			

Part B: Interest

	The term	Not at all interested in learning more	Interested in learning more	Very interested in learning more
1	Observation			
2	Classification			
3	Measuring			
4	Inferring			
5	Hypothesizing			
6	Experimenting			
7	Identifying Variables			
8	Formulating Models			
9	Interpreting Data			
10	Predicting			
11	Controlling Variables			
12	Graphing			
13	Communication			

APPENDIX B

Section 2: Defining science process skills

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

Observe:____

Classify:

Measure:

Infer:

Hypothesize:

Experiment:

Section2: Defining Process Skills (continued)

Variable:____

____

____

Model:____

____

____

Interpret Data:____

____

____

Predict:____

____

____

Communication:____

____

____

Graphing:____

____

____

APPENDIX C

Test of Basic and Integrated Process Skills

Instructions:

1. This will in NO WAY be associated to your grade in your science methods course.
2. Only indicate your initials on the given answer sheet.
3. Attempt all questions and provide your answer by shading the appropriate bubble on the given answer sheet.
4. You will not be associated with your answers once you have completed the questionnaire.

1. Last week Caden went looking for small creatures. This chart shows where he looked and what he found.

LOCATION		SPIDERS	SOWBUGS	WORMS
Under an old log		8	3	2
In a pile of leaves		4	6	3
Under rocks		2	3	7
In the grass		7	9	5

Where was the best place to find worms?

A. Under an old log

B. Under a pile of leaves

C. Under rocks

D. In the grass

2. Susan is studying food production in bean plants. She measures food production by the amount of starch produced. She notes that she can change the amount of light, the amount of carbon dioxide, and the amount of water that plants receive. What is a testable hypothesis that Susan could study in this investigation?

A. The more carbon dioxide a bean plant receives the more starch it will produce.

B. The more starch a bean plant produces the more light it needs.

C. The more water a bean plant gets the more carbon dioxide it needs.

D. The more lights a bean plant receives the more carbon dioxide it will produce.

3. A green house manager wants to speed up the production of tomato plants to meet the demands of anxious gardeners. She plants tomato seeds in several trays. Her hypothesis is that the more moisture seeds receive the faster they sprout. How can she test this hypothesis?

A. Count the number of days it takes seeds receiving different amounts of water to sprout.

B. Measure the height of the tomato plants a day after each watering.

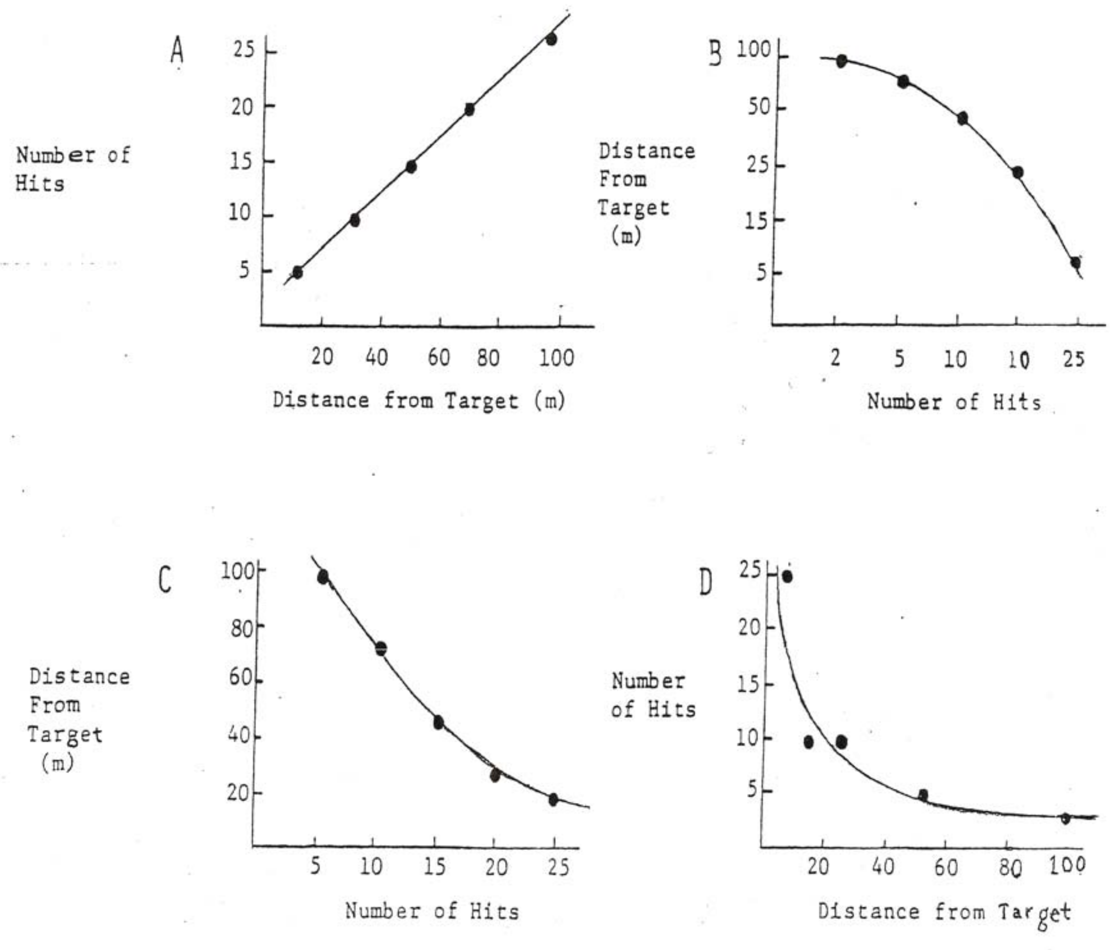
C. Measure the amount of water used by plants in different trays.

D. Count the number of tomato seeds placed in each of the trays.

4. Twenty-five shots are fired at a target from several distances. The table below shows the number of 'hits' in 25 shots at each distance.

Distance from Target (m)	Number of Hits
5	25
15	10
25	10
50	5
100	2

Which graph best represents the data?



A study was done to see if leaves added to soil had an effect on tomato production. Tomato plants were grown in four large tubs. Each tub had the same kind and amount of soil. One tub had 15 kg of rotted leaves mixed in the soil and a second had 10 kg. A third tub had 5 kg and the fourth had no leaves added. Each tub was kept in the sun and watered the same amount. The number of kilograms of tomatoes produced in each tub was recorded.

5. What is the hypothesis being tested?

   A. The greater the amount of sunshine, the greater the amount of tomatoes produced.

   B. The larger the tub, the greater the amount of leaves added.

   C. The greater the amount of water added, the faster the leaves rotted in the tubs.

   D. The greater the amount of leaves added, the greater the amount of tomatoes produced.

6. What is a controlled variable in this study?

   A. Amount of tomatoes produced in each tub.

   B. Amount of leaves added to the tubs.

   C. Amount of soil in each tub.

   D. Number of tubs receiving rotted leaves.

7. What is the dependent or responding variable?

   A. Amount of tomatoes produced in each tub.

   B. Amount of leaves added to the tubs.

   C. Amount of soil in each tub.

   D. Number of tubs receiving rotted leaves.

8. What is the independent or manipulated variable?

   A. Amount of tomatoes produced in each tub.

   B. Amount of leaves added to the tubs.

   C. Amount of soil in each tub.

   D. Number of tubs receiving rotted leaves.

9. Vance was watching a squirrel in a tree. What could he tell about the squirrel <u>just from looking at it?</u>

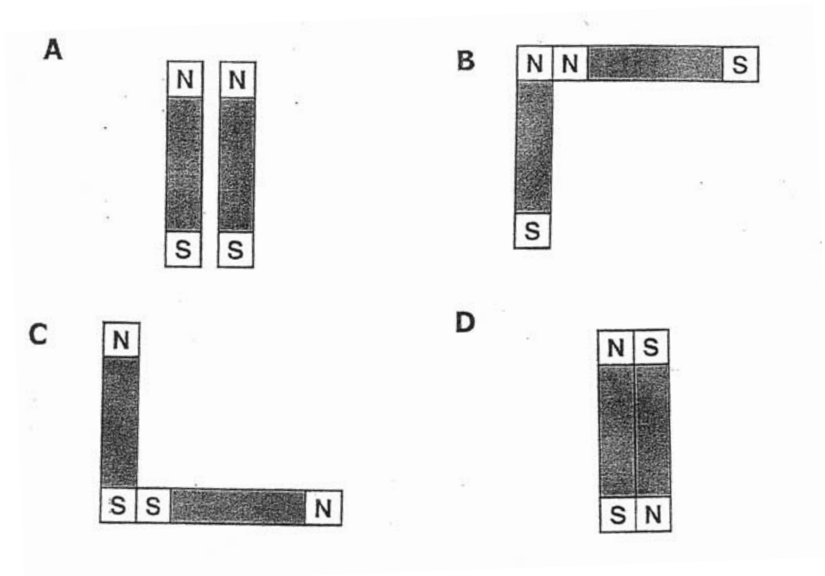
   A. The squirrel was brown and had a bushy tail.

   B. The squirrel was 2 years old.

   C. The squirrel was looking fro food for its babies.

   D. The squirrel was hungry.

10. Which picture shows the way that two magnets will attract?



11. Jim thinks that the more air pressure in a basketball, the higher it will bounce. To investigate the hypothesis he collects several basketballs and an air pump with a pressure gauge. How should Jim test his hypothesis?

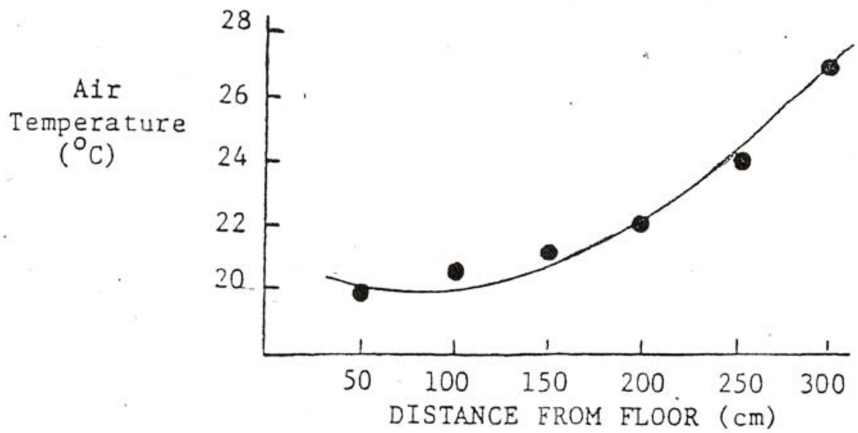
    A. Bounce basketballs with different amounts of force from the same height.

    B. Bounce basketballs having different air pressures form the same height.

    C. Bounce basketballs having the same air pressure at different angles from the floor.

    D. Bounce basketballs having the same amount of air pressure from different heights.

12. A study is done of the temperature in a room at different distances above the floor. The graph of the data is shown below. How are the variables related?



   A. As distance from the floor increases, air temperature decreases.

   B. As the distance from the floor increases, air temperature increases.

   C. An increase in air temperature means a decrease in distance from the floor.

   D. The distance from the floor is not related to air temperature increases.

13. Devin is studying the effect of temperature on the rate that oil flows. His hypothesis is that as the temperature of the oil increases it flows faster. How could he test this hypothesis?

   A. Heat oil to different temperatures and weigh it after it flows out of the can.

   B. Observe the speed at which oil at different temperatures flows down a smooth surface.

   C. Let oil flow down smooth surfaces at different angles and observe its speed.

   D. Measure the time it takes for oil of different thicknesses to pour out of the can.

14. Your mother is burning a candle. It has melted 3 centimeters in the past 3 hours. Use this information. What do you think will happen in the next three hours?

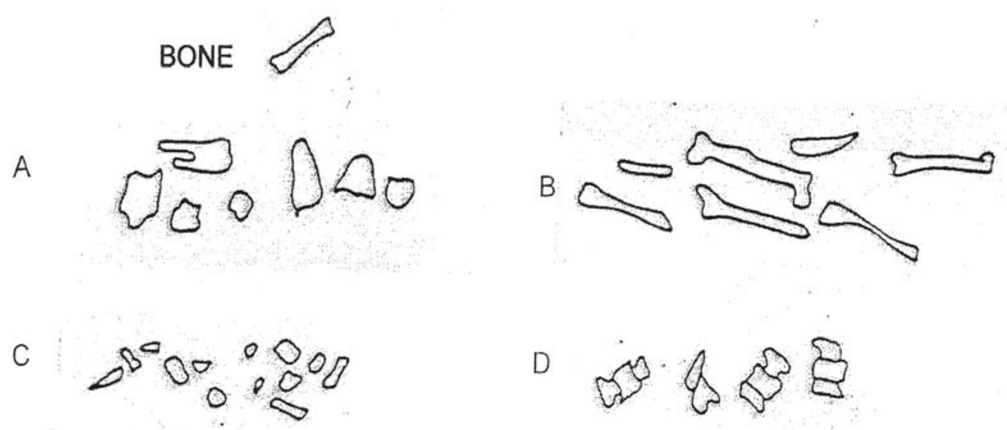
    A. The candle will stop melting.

    B. The candle will melt 3 more centimeters.

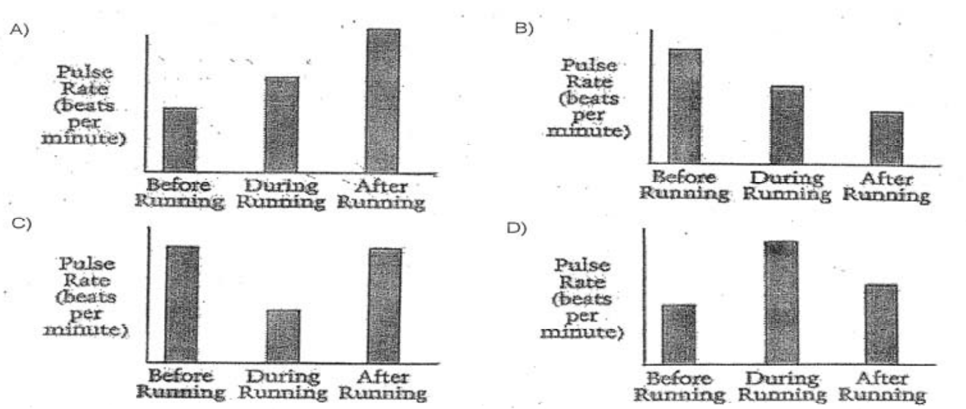
    C. The candle will melt 6 more centimeters.

    D. The candle will melt 1 more centimeter.

15. A scientist found this bone in a cave. Which group of bones should it be in?



16. Ryan wanted to know how his pulse rate changed when he ran very fast. He measured his pulse rate before he started running, while he was running, and two minutes after he stopped running. Which graph best shows how Ryan's pulse rate changed?



Reita wondered if the earth and oceans are heated equally by sunlight. She decided to conduct an investigation. She filled a bucket with dirt and another bucket of the same kind with water. She placed them so each bucket received the same amount of sunlight. The temperature in each was measured every hour from 8:00 a.m. to 6:00 p.m.

17. What is the hypothesis being tested?

    A. The greater the amount of sunshine, the warmer the soil and water become.

    B. The longer the soil and water are in the sun, the warmer they become.

    C. Different types of material are warmed differently by the sun.

    D. Different amount of sunlight are received at different times of the day.

18. What is a controlled variable in this study?

    A. Kind of water placed in the bucket.

    B. Temperature of the water and soil.

    C. Type of material placed in the buckets.

    D. Amount of time each bucket is in the sun.

19. What is the dependent or responding variable?

    A. Kind of water placed in the bucket.

    B. Temperature of the water and soil.

    C. Type of material placed in the buckets.

    D. Amount of time each bucket is in the sun.

20. What is the independent or manipulated variable?

    A. Kind of water placed in the bucket.

    B. Temperature of the water and soil.

    C. Type of material placed in the buckets.

    D. Amount of time each bucket is in the sun.

21. Cathy was playing in the park. She spotted an animal in the bushes. Which sentence tells you the most about what the animal <u>looked like</u>?

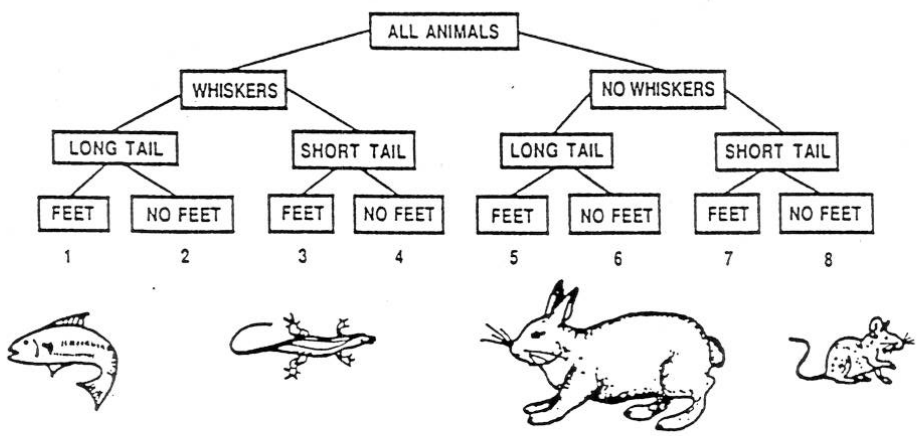
    A. It was brown with whiskers and scared.

    B. It was tired and had big eyes.

    C. It was small with four legs.

    D. It looked like a mouse with a short tail.

22. Falan and her father went to the pet store. They classified the animals they saw this way.



    Which animal belongs in Box 1?

    A. Fish

    B. Lizard

    C. Rabbit

    D. Mouse

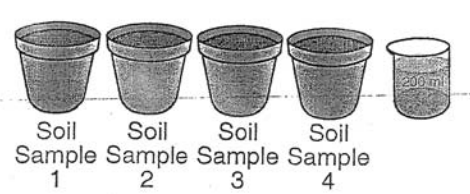
23. To find out which soil absorbs (holds) moisture *best,* each container shown must…

    A. Be made of a different material.

    B. Have soil from the same place.

    C. Be tested by the same person.

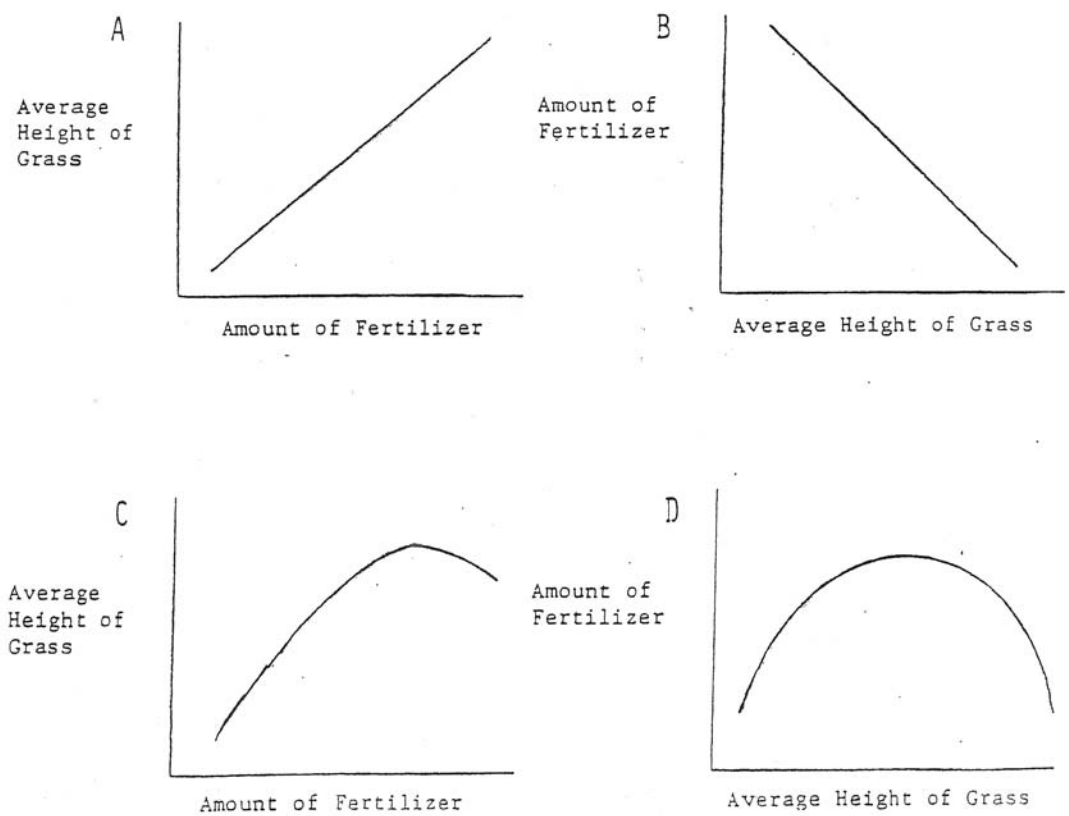
    D. Contain the same amount of soil.



24. A researcher is testing a new fertilizer. Five small fields of the same size are used. Each field receives a different amount of fertilizer. One month later the average height of the grass in each plot is measured. The measurements are shown in the table below.

Amount of Fertilizer (kg)	Average Height of Grass (cm)
10	7
30	10
50	12
80	14
100	12

Which graph represents the data in the table?



25. A student wants to cut a piece of string for a class activity. The length of the string is measured best in which units?

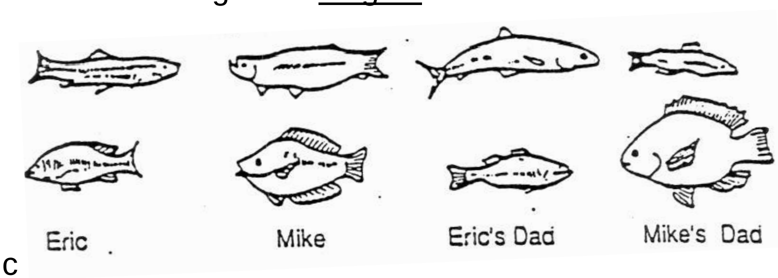
    A. Gallons

    B. Liters

    C. Miles

    D. Centimeters

26. Last week Eric and Mike went fishing with their fathers. They each caught 2 fish. Who caught the longest fish?



    A. Eric

    B. Mike

    C. Eric's Dad

    D. Mike's Dad

27. Cindy and Erin did a project in science class. They recorded the temperature of the water each minute. This chart shows what they found.

TIME	TEMPERATURE OF WATER
1 minute	18 ˚C
2 minutes	22 ˚C
3 minutes	25 ˚C
4 minutes	29 ˚C
5 minutes	--- ˚C

What do you think the temperature of the water will be after 5 minutes?

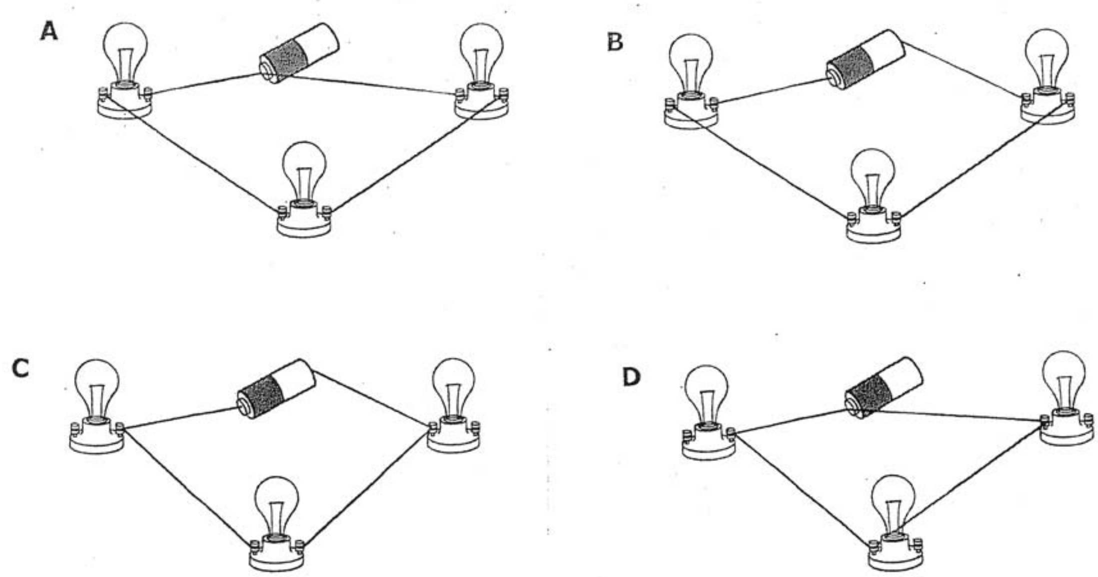
    A. 26 ˚C

    B. 29 ˚C

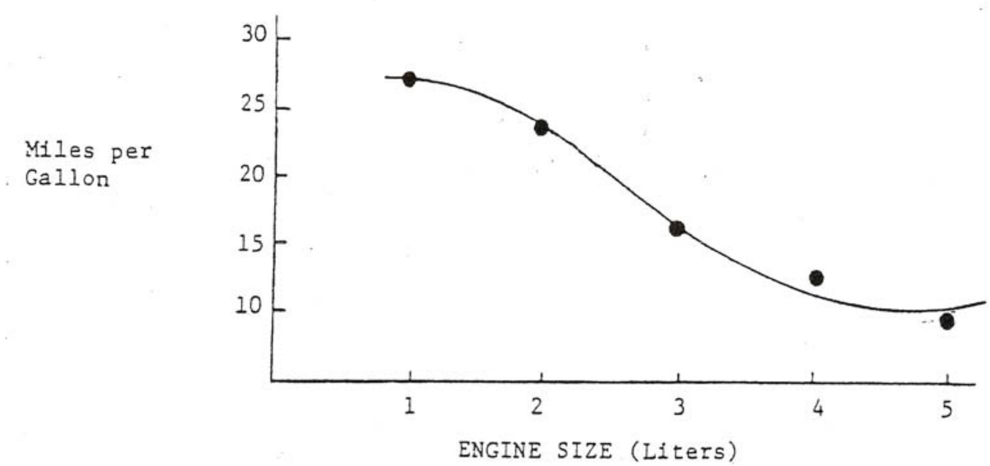
    C. 32 ˚C

    D. 35 ˚C

28. A class prepared some electric circuits using a battery, connecting wires, and three light bulbs. Which of these circuits can make the three bulbs light?



29. A consumer group measures the miles per gallon cars get with different size engines. The results are as follows:



Which of the following describes the relationship between the variables?

A. The larger the engine the more miles per gallon the car gets.

B. The fewer miles per gallon the car gets the smaller the engine.

C. The smaller the engine the more miles per gallon a car gets.

D. The more miles per gallon for a car the larger the engine.

Marc wanted to find out if the temperature of water affected the amount of sugar that would dissolve in it. He put 50ml of water into each of four identical jars. He changed the temperatures of the jars of water until he had one at 0˚C, one at 50˚C, one at 75˚C, and one at 95˚C. He then dissolved as much sugar as he could in each jar by stirring.

30. What is the hypothesis being tested?

    A. The greater the amount of stirring, the greater the amount of sugar dissolved.

    B. The greater the amount of sugar dissolved, the sweeter the liquid.

    C. The higher the temperature, the greater the amount of sugar dissolved.

    D. The greater the amount of water used, the higher the temperature.

31. What is a controlled variable in this study?

    A. Amount of sugar dissolved in each jar.

    B. Amount of water placed in each jar.

    C. Number of jars used to hold water.

    D. The temperature of the water.

32. What is the dependent or responding variable?

    A. Amount of sugar dissolved in each jar.

    B. Amount of water placed in each jar.

    C. Number of jars used to hold water.

    D. The temperature of the water.

33. What is the independent or manipulated variable?

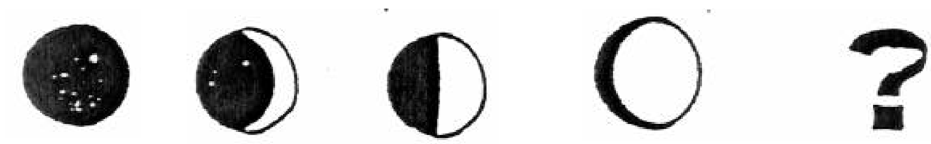
    A. Amount of sugar dissolved in each jar.

    B. Amount of water placed in each jar.

    C. Number of jars used to hold water.

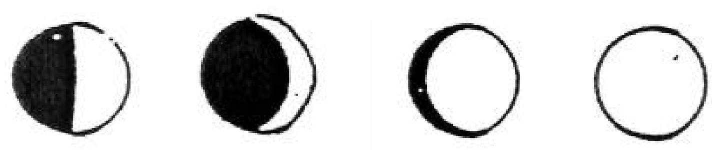
    D. The temperature of the water.

34. Dustin and Kalen went to summer camp. At night they looked at the moon and noticed these changes.



DAY 1 DAY 4 DAY 8 DAY 12 DAY 16

What will the moon look like next?



A. B. C. D.

35. Last week 8 of your fish died. Two are still alive. What is the best explanation for what happened?

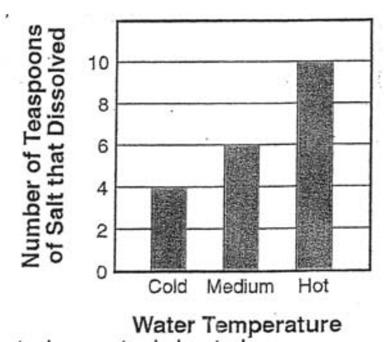
A. The fish got old.

B. The fish got lonely.

C. The fish had a disease.

D. Two fish died Sunday.

36. The graph shows what happened when salt was added to water in a glass. According to the graph, which of these is correct?



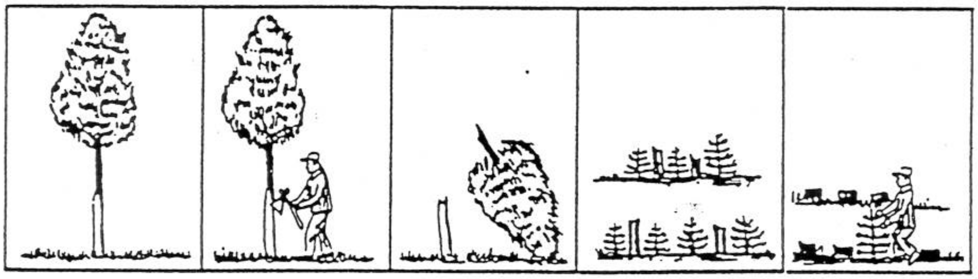
A. Salt tastes different when water is heated.

B. Salt will cause water to heat up.

C. Salt is used to make hot water.

D. Salt dissolves more easily in hot water.

37. What story does this set of pictures tell?



A. The man cut down a large tree. He used it for firewood.

B. Lightning killed a large tree. The man planted some smaller trees.

C. A man cut off some branches from a large tree. He planted some smaller trees.

D. The man cut down a large tree. He planted some smaller trees.

38. A football coach thinks his team loses because his players lack strength. He decides to study factors that influence strength. Which of the following variables might the coach study to see if it affects the strength of the players?

A. Amount of vitamins taken each day.

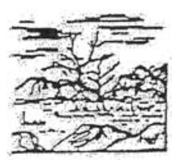
B. Amount of lifting exercises done each day.

C. Amount of time spent doing exercises.

D. Amount of water each player drinks daily.

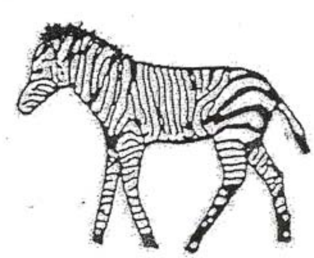
39. A lion was hunting for his dinner. A zebra saw the lion and knew she had to hide. What would be the <u>best</u> hiding place for this zebra?

A. 

B. 

C. 

D. 



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

41. A class is studying the speed of objects as they fall to the earth. They design an investigation where bags of gravel weighing different amounts will be dropped from the same height. In their investigation, which of the following is the hypothesis they would test about the speed of objects falling to earth?

A. An object will fall faster when it is dropped further.

B. The higher an object is in the air the faster it will fall.

C. The larger the pieces of gravel in a bag the faster it will fall.

D. The heavier an object the faster it will fall to the ground.

42. Fred has two kinds of plant food, “Quickgrow” and “Supergrow.” What would be the best way for Fred to find out which plant food helps a particular type of houseplant grow the most?

A. Put some Quickgrow on a plant in the living room, put some Supergrow on a plant of the same type in the bedroom, and see which one grows the most.

B. Find out how much each kind of plant food costs, because the more expensive kind is probably better for growing plants.

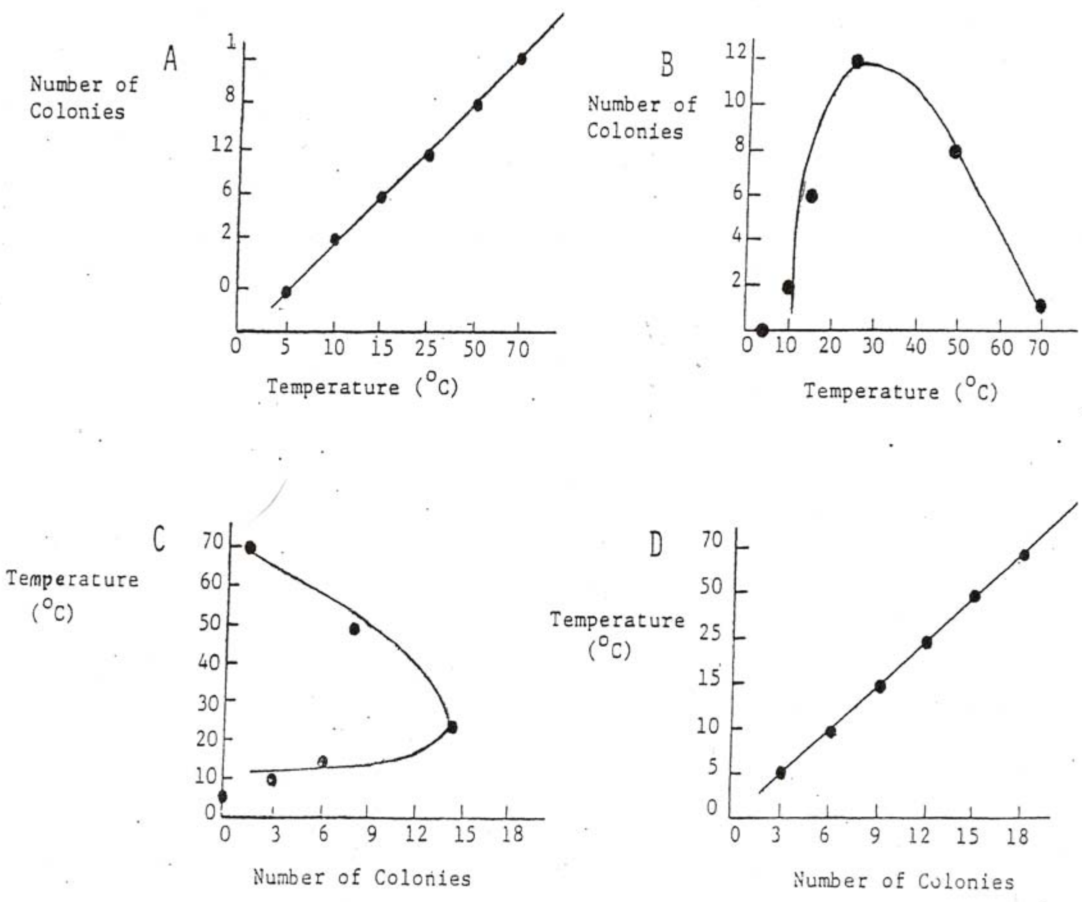
C. Put some Quickgrow on a few plants, put the same amount of Supergrow on a few other plants of the same type, put all the plants in the same place, and see which group of plants grows the most.

D. Look at the advertisements for Quickgrow, look at the advertisements for Supergrow, and see which one says it helps plants grow the most.

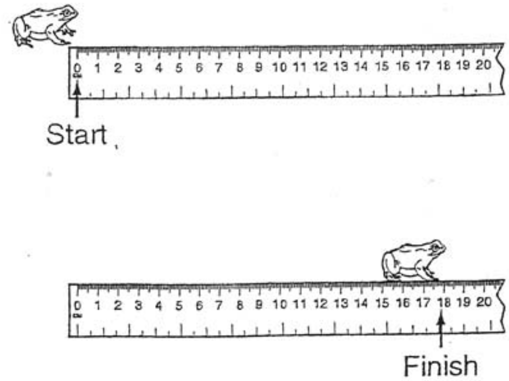
43. A student in a science class studied the effect of temperature on the growth of bacteria. The student obtained the following data:

Temperature of growth chamber (^0C)	Number of bacterial colonies
5	0
10	2
15	6
25	12
50	8
70	1

Which graph correctly represents the data from the experiment?



44. Using the picture, which measurement is closes to how far the frog jumped?



A. 12 centimeters (cm)

B. 14 centimeters (cm)

C. 18 centimeters (cm)

D. 20 centimeters (cm)

45. Dawn found an old tree deep in the woods. She wanted to tell her friends how to get there. What would be the <u>most important</u> thing to know?

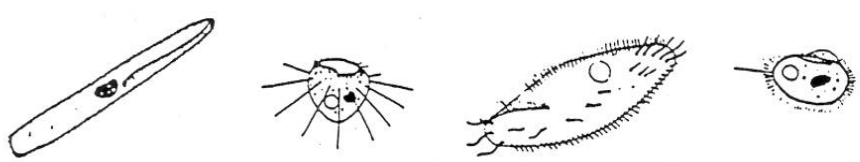
A. The direction and distance she went.

B. How many fields she passed along the way.

C. What the tree looked like.

D. What time she got there.

46. Selena brought a jar of pond water to class. She looked at the water under a microscope. She saw these creatures. What do <u>all</u> of these creatures have?



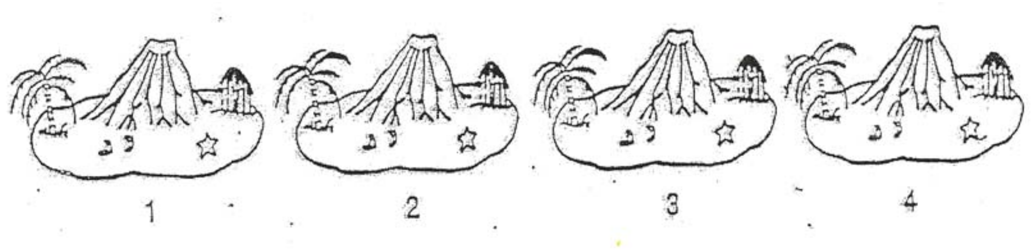
A. A large dark spot

B. Round shape

C. Hairs

D. A large white spot

47. Which island has something missing?



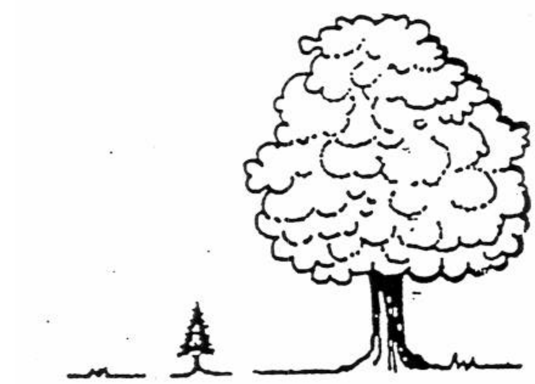
A. 1

B. 2

C. 3

D. 4

48. Use the small tree as a measure. How many trees high is the large tree?



A. 3

B. 4

C. 5

D. 6

This instrument is the compilation of several instruments. The following instruments were used to develop this instrument. Their authors and the associated questions are listed below:

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.

BIPS Question number: 2-8, 11-13, 17-20, 24, 29-33, 38, 41, 43

Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2005 Science Assessment.

BIPS Question number: 16, 42

Padilla, M., Cronin, L., & Twiest, M. (1985). 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.

BIPS Question number: 1, 9, 14, 15, 21, 22, 26, 27, 34, 35, 37, 39, 40, 45-48

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Form S0117, Core 1. Released Test, Grade 3, Science.

BIPS Question number: 11, 25, 36, 44

Form S0117, Core 1. Released Test, Grade 5, Science.

BIPS Question number: 23, 28

Appendix D

COMMONWEALTH *of* VIRGINIA

DEPARTMENT OF EDUCATION
Division of Assessment and Reporting
P. O. Box 2120
Richmond, Virginia 23218-2120

April 7, 2010

Via e-mail to ewilson4@siu.edu

TO: Erin Miles

FROM: Shelley Loving-Ryder, Assistant Superintendent
Division of Student Assessment and School Improvement

SUBJECT: Copyright Permission

This is written in response to your e-mail request to use materials copyrighted by the Virginia Department of Education (VDOE). Specifically, you requested use of the Virginia Standards of Learning mathematics and science released tests located at the following links:

http://www.doe.virginia.gov/testing/sol/released_tests/2007/test07_science3.pdf
http://www.doe.virginia.gov/testing/sol/released_tests/2007/test07_science5.pdf

You stated in your request that the items will be used to complete the research requirement for a Master's thesis in Curriculum and Instruction, Science Education specialty and that the questions will be used in conjunction with several other research based science process questions. You also stated that the audience will be in-service teachers in the state of Illinois and higher education professionals in the Teacher Education field. Finally you stated that the test items will in no way be used for commercial purposes.

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Should you have questions, please call (804) 225-2102 or send an e-mail to Student_Assessment@doe.virginia.gov .

APPENDIX E

The following pages provide teachers' given definitions for the specified science process skills. Responses marked with an asterisk (*) were rated as 'correct.'

Observe: To use the five senses to gather information about an object or event.

1. To watch and make observations/notes on what occurs.
2. Using all senses to gather information*
3. What you see, hear, smell, taste (if safe), feel when looking at an object*
4. To watch, look and take notes on what you see happening
5. To identify characteristics of objects and experiences
6. To note physical details with specific means, measuring, noting differences in time, etc.
7. Taking data on an event you watch
8. To watch and learn the outcome
9. To look at something and take note of shape, size, texture - any characteristics
10. What do you see, hear, feel, etc? What is happening?
11. To observe means to use your senses to interpret the world around you.
12. Something you can use your senses to explain
13. Take note of what you see, smell, taste, touch*
14. What you see happening. Any observation --> sight, hear, taste, touch, smell
15. What you see happen (or smell, taste, hear, feel)
16. To look at something and use all available senses to make judgments about something
17. To look at something closely
18. Using one's senses to collect information*

19. To observe is to watch an object or event and record any noticeable changes, occurrences, or lack there of
20. To look and watch something happen
21. Using all senses to gather information*
22. To look at things and watch how they change
23. Watching or looking at something such as an experiment to determine data and statistics from it
24. To look at closely and carefully

Classify: To group or order objects or events into categories based on properties, characteristics, criteria, or an established scheme.

1. Place items into a category
2. Sort and organize objects/thing
3. Putting things in groups based on observations and characteristics*
4. To organize or group according to characteristics*
5. To order things related to their characteristics*
6. Put objects into categories based on attributes*
7. To put things in a certain category
8. To put objects into group based on their characteristics or traits*
9. To organize things into groups basic on some commonality*
10. Arranging something by a certain system
11. To classify is to place into groups by defined characteristics*
12. Organize information by certain traits

13. Put into groups based on characteristics*
14. Putting something in a group because of certain qualities is has*
15. Grouping by attributes
16. To divide items into groups by characteristics*
17. Put something into a category
18. Putting objects with similar characteristics into groups
19. To classify is to sort and categorize items into related groups
20. To put things into similar groups
21. Sort/place objects or ideas into categories
22. To sort into groups of like sizes, shapes, or colors
23. Putting objects into groups based on different characteristics*
24. To put into groups

Measure: To use standard and nonstandard measures or estimates and their appropriate instruments to describe the dimensions of an object, substance, or event in quantitative terms.

1. Determine how much of a material
2. A way to determine how much of something there is.
3. Quantifying an object whether by length, height, weight, etc
4. To use a unit to define how much of or an amount
5. To determine size shape or volume and other characteristics using standard units of comparison

6. To use specific scales to observe variances change over time, distance, weight, etc.
7. Using a standard unit to identify amount or size
8. Find a length or volume of objects
9. To find weight, length or volume
10. Finding the length, weight, etc. of an object
11. To determine a quantity or to define by size
12. Use a standard unit to define something
13. Define the amount of something, show change over time
14. Give a weight or measurement to something to help you record information, i.e. weight, length, meters, lbs,
15. To evaluate an amount using a standard measure/unit
16. Put something in units
17. To find out the length of something, or the volume of something, or the mass of something
18. Collecting specific data such as volume mass length, etc
19. To measure is to assign a frame of reference to something according to its properties using a standard scale of measurement
20. To see how much we have of something
21. A way to communicate an amount of anything - including measures in percentages, (volume, temp, area, length, weight, etc)
22. To find out how much matter is an object
23. Giving a scale of weight, length, volume, etc to something for further statistics

24. To determine the amount

<u>Infer</u>: To make suggestions, conclusions, assumptions, or explanations about a specific event based on observation and data.

1. Conclude or predict based on information
2. Read results of an experiment or procedure
3. Making an educated guess based on observation
4. To assume/predict according to what you know, the outcome.
5. To develop meaning and explanation from observed experiences and observations*
6. To form a decision based on data regarding specific situations*
7. Put meaning into something without directly saying it
8. Guess an outcome that may happen based on your background knowledge
9. To take what you do know and make assumptions based on that knowledge. If/then type of thinking
10. What did you learn from this? What do you think is going to happen?
11. To formulate a "guess" based on available information
12. Make a conclusion from given information*
13. Use information and experience to draw your own conclusions
14. What you think may happen
15. To use what you know or observe to decide what you thin might happen or what has happened
16. To use information you gain and also you prior knowledge to draw a conclusion.

17. An assumption of what will happen
18. Like making conclusions, using the outcome of your experiment to make generalizations and connections*
19. To infer is to find meaning and understanding via learned material and experiences
20. To give reference to objects or things
21. To presume something based on information not directly stated.
22. Guess
23. To make sense of something based on the information given*
24. To deduce, using known information*

Predict: To state the outcome of a future event based on a pattern of evidence, past experience, or observations.

1. What you think will happen
2. Use your knowledge to make a guess on what will happen based on the results
3. Make a reasonable guess based on what you know
4. To make a guess
5. To discuss possible outcomes of events
6. The process of figuring out what will happen in a given situation.
7. To guess the outcome of an event
8. Guess a possible outcome that you feel will happen
9. Guess what will happen
10. What you think will happen

11. To determine a likely outcome based on interpreted data*
12. Guess on an outcome
13. Use information an knowledge to decide what you think will happen*
14. What you think may happen
15. Stating what you think will happen
16. Guessing what you think will happen based on what you know*
17. To tell what you think will occur
18. Making an educated guess as to the outcome
19. To predict is to state what you expect to happen when something happens
20. To make a guess about something
21. Forecast the outcome based on knowledge of variables, control, and background of knowledge*
22. To make a guess to an outcome
23. Making an educated guess about your experiment using prior knowledge*
24. To make a hypothesis, a good guess as to what will happen in a given situation

Communication: 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.

1. Discussing ideas
2. Discuss the results/outcome of an experiment
3. Communicate data be able to explain what you know
4. To report and tell others what is happening

5. To share thoughts, ideas, and understandings with others
6. The means of presenting gathered information and interpreted data.
7. To be able to tell other professional or students something so they can comprehend it
8. Talk about what your data showed
9. To talk or write information to share with others
10. Sharing your ideas and listening to others
11. Transferring and sharing knowledge, information and ideas
12. Sharing of information
13. Sharing ideas and information with others*
14. Interaction, telling/writing about your findings
15. Exchanging information
16. Showing and explaining to others (strikethrough: what you have) knowledge gained*
17. To tell orally the results. To present your information
18. Sharing the results of your experiment with others, either through graphs, written reports, displays, etc*
19. To share ideas via various means-speaking, reading, etc
20. To talk with one another, answer questions and make predictions together
21. Report data collected about experiment and outcome
22. To talk or express your thoughts and findings
23. Being able to tell, write and discuss what is happening to your experiment
24. To write, speak, draw in order to explain a concept or idea

Hypothesize: To state verifiable relationship between variables and their expected outcome in an experiment or problem to be solved.

1. Educated guess
2. Formulate an education guess
3. A possible solution based on your observations and inference
4. To make a statement according to data that you have collected, to what happened
5. To predict possible outcomes based on cause and effect*
6. To form a question which can be tested through experimentation
7. To make an educated guess
8. Use what you know and take into account the materials you are working with and decide what outcomes are likely
9. To take an educated guess about what you think the results will be
10. What you think will happen based on an experiment
11. To propose an idea based on observations that has not been thoroughly tested
12. Educated guess
13. Decide what you think will be the outcome of an experiment
14. Making an educated guess on the results or findings
15. To infer what you think will happen in a situation with known component(s) and procedure(s)
16. Use your inferences made and make an educated guess about something
17. Make a guess as to what you think will happen
18. Making a prediction based on prior knowledge and observations as to the outcome of an experiment

19. To formulate an idea of predicted outcomes and expectations prior to testing it
20. To make a guess or prediction about what’s going to happen
21. A reasonable "guess" about an outcome based on background of knowledge
22. Educated guess
23. Make a prediction based on prior knowledge. Your prediction will be tested through experimentation
24. To make an educated guess

Experiment: To determine and execute reasonable procedures to test an idea or hypothesis using observation, identifying and controlling variables, collecting and interpreting data, measuring, and manipulating materials.

1. Conduct a test to determine an outcome
2. Conduct something that will test your educated guess or hypothesis
3. Testing your hypothesis
4. To test or evaluate. To gather information that will show what is true or not
5. To test hypothesis by controlling variables and measuring outcomes*
6. To devise a controlled process to test validity at a specific hypothesis
7. To control and event to find an outcome
8. Test a procedure step by step to get a result*
9. To actually test a hypothesis and get results
10. What you actually do to test your hypothesis*
11. A measure of evaluating or testing a hypothesis*
12. Test to find or answer a question about something

13. Conduct an activity to answer a question or prove or disprove a hypothesis*
14. Test your hypothesis to see if you are correct
15. Testing a problem using a standardized method - use a control and variables*
16. Something you do to test a hypothesis*
17. A procedure to check your hypothesis*
18. Following a set of steps to test one's hypothesis*
19. To test an idea to see if it is valid using observations, tasks, and data*
20. To take given data and follow through with your prediction. Test your guess
21. Using a control (trial with no variables) apply variables to other trials in order to determine the degree of accuracy for a hypothesis*
22. To carry out a plan of how something will turn out
23. Testing your hypothesis and recording data to prove whether your hypothesis is right or wrong or close*
24. To test an idea using various means

Variable: Any changeable factors that can affect an experiment, including those that may need to be kept constant for the purpose of determing causation.

1. Something that can change, some stay the same.
2. A condition that affects the results of an experiment/test*
3. Something that changes in an experiment
4. A part of a experiment that can change*
5. Conditions that influence results or effects
6. The part of an experiment which is either changed or controlled.

7. A known or unknown circumstance that could occur during an experiment
8. One thing in an experiment that is changed to see how an experiment is different
9. Part of an experiment/conditions; could be controlled
10. What can be controlled in an experiment
11. A factor in an experiment that may be independent or controlled
12. A change-something you are testing
13. One piece of an experiment that can be controlled or changed to learn about the outcomes*
14. Something that is kept constant
15. Something that changes/is changed in a set procedures
16. The thing that changes and doesn't remain constant in an experiment
17. Something that is able to be changed or controlled
18. A factor in the experiment which affects the outcome*
19. A variable is something that changes in an experiment, thus changing the data*
20. Is a, something that is changed or controlled during an experiment
21. Any condition that affects the outcome of an experiment*
22. Part of an experiment that changes
23. Something that changes in an experiment that may change the data*
24. Something that is able to be changed or manipulated

Model: A mental, pictorial, written or physical representation to explain an idea, object, or event.

1. What things should look like

2. Representation of something that is of a large scale
3. Demonstrate your experiment
4. To show, demonstrate
5. To simulate real objects or events
6. A way to demonstrate a specific set of criteria to show what will happen in a particular situation.
7. To demonstrate a particular event or behavior
8. Make something physical to look at or test in order to test an experiment
9. Make an example to physically work with
10. The actual experiment?
11. A representation of an object. Example - a globe is a model of the Earth*
12. Example of something
13. A diagram or physical representation of a concept*
14. A diagram of your findings
15. A replica/representation of a structure. Models may be larger than life size as for a cell or smaller than life size as a solar system*
16. Using something either smaller or larger than an original to help solve a problem
17. To show or do the actual experiment
18. Building a true-to-life but smaller representation of whatever it is you are doing
19. A model is a physical or pictorial representation of a concept of process*
20. Is a hands on description of anything
21. A representation of a larger object or idea
22. Something to look at for an example

23. A diagram that represents what you are doing or are going to do in your experiment
24. A representation of something. A globe is a model of the Earth

Interpret data: To treat or transform data through finding patterns, graphs, or tables in order to make it meaningful and draw conclusions from it.

1. Look at results and determine if hypothesis is correct or not.
2. Read and understand the results of the experiment. Formulate ideas based on the understanding of the results
3. Analyzing and being able to tell what is given in your data
4. To take information and make a determination of what happened
5. To arrive at conclusions by observing trends and relationship*
6. Using information from an experiment or observation to make a decision about the experiment or observation. *
7. To take the data and put it into some sort of meaning*
8. Look at results from your experiment
9. Look at results from an experiment
10. What you can gather from the information you have collected, or what you learned from the experiment
11. Viewing the results of an experiment and organizing these results into useful information
12. Using information to make a conclusion
13. Analyze results and compare information

14. What you found in your experiment and gathering it all together
15. Taking data and putting in a usable form and making inferences from it-drawing conclusions from information gathered*
16. Looking at data gained from an experiment and deciding what it means*
17. Look at the results of the experiment
18. Using the outcome of your experiment to predict future events, draw inferences, and make conclusions
19. It means to find meaning, relationships and patterns in a set of information*
20. To understand gathered data that's placed on a graph
21. Take information and decide what it means and what the implications are*
22. To look at results and see what your experiment has done
23. Analyzing data from your experiments to understand what is happening in your experiment*
24. To look at information from an experiment and determine its meaning and come to a conclusion*

Graphing: Using information about the data as numerical quantities and converting into a diagram or picture that shows the relationships among the quantities.

1. Putting data on a chart
2. Plotting and displaying data from an experiment
3. Graph the data into reasonable graphs
4. To show data on paper, in an organized, way.
5. To represent in a picture relationship between events*

6. A way to relate and communicate about data.
7. Putting data into a meaning organization of data
8. Graph points or outcomes from what you experiment showed
9. Using math to chart results. A way to organize results
10. Way of communicating your data
11. Visually representing data in a way that communicates the purpose of the data*
12. Organizing data
13. Using data to show results in a different ways, perhaps to show change
14. Showing results on a type of graph
15. Representing data on a grid or in some other representative form
16. Putting data into charts/graphs to organize data
17. Putting the results into a table
18. Using the data you collect and putting it into a visual form to communicate results*
19. To represent data in an organized set of pictures and resources
20. To put data together in an organized manner
21. Putting data into a visual graphic form in order to better deliver info about results
22. To make a chart of results
23. Putting your data in an organized manner to make it easier to communicate
24. To take data and put in a form that is visually easy to understand. Pie, circle, bar, line, chart.

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