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What Type and Level of Science Content Knowledge of Elementary Education Students Affect Their Ability to Construct an Inquiry-Based Science Lesson?

Gail R. Luera
Richard H. Moyer
Susan A. Everett
University of Michigan–Dearborn

Although various governmental and professional organizations recommend that teachers use an inquiry-based approach to science education, most teachers do not use this pedagogy. Lack of content knowledge and/or insufficient skills in planning inquiry-based lessons may contribute to teachers' reluctance to utilize this methodological approach. This study explores the relationship between science content knowledge and inquiry-based lesson planning ability. The authors found a significant positive relationship between content knowledge and the ability to create an inquiry-based science lesson. These data are of great interest since proficiency in lesson-planning is believed to contribute significantly to the ability to teach an inquiry-based lesson.

Elementary teachers are expected to know science content and be able to teach science using an inquiry approach (National Research Council [NRC], 1996). Often, the content is determined by the teachers' state science standards or benchmarks. Many times, teachers fall short of these expectations. This is partly because they lack content knowledge (Greene, 1990) and/or the ability to develop inquiry-based lessons (Crawford, 1999; Stofflett & Stoddart, 1994). Are these two objectives related? Is science content knowledge a prerequisite to developing an inquiry lesson? Our interest in answering this question was piqued as we saw our students' struggle writing lesson plans. Was it because they had inadequate content knowledge? All three authors have heard students comment about how they had to learn the content before they could write a lesson plan.

Knowing the factors that affect the ability to construct an inquiry-based science lesson has wide significance. The answer will enable science educators to better meet the goals stated by agencies such as the NRC's (1996) *National Science Education Standards* (*NSES*) and assist university faculty in preparing future teachers who do know science content and use an inquiry-based pedagogy. This study represents an initial attempt to answer this question by investigating, "What type and to what level of sophistication of science content knowledge is a prerequisite to designing inquiry-based science lessons?"

Background

Approaches to Teaching Inquiry

Although the term "inquiry" is used widely, there are many different definitions for what it means to teach using this method. Definitions range from "hands-on" (Shymansky, Kyle, & Alport, 1983); to "having students ask questions about the world in which they live" (Barman, 2002); to "a continuum of strategies, ranging from a very open-ended approach to a more teacher-guided strategy" (Martin-Hansen, 2002). One of the difficulties in determining the impact of inquiry-based science is having science educators come to a common definition of the term (Anderson, 2002). If researchers use the term "inquiry" in different ways, then it is no wonder that education students and practicing teachers have difficulty defining this concept in relation to their own teaching (Barman, 2002; Gerking, 2003). We are adopting the view of the *NSES* that describes inquiry in three different ways: (1) scientific inquiry, (2) inquiry learning, and (3) inquiry teaching. For example, "Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (NRC, 1996, p. 23); inquiry learning "refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (p. 23); and for teaching, "Inquiry into authentic questions generated from student experiences is the central strategy for teaching science" (p. 31). It is important to note that the *NSES* classifies inquiry as one of the eight content areas (p. 104). Since inquiry is a content area, similar to physical science or life science, then it follows that there are a myriad of pedagogues that could be used to teach it. Different pedagogues that are appropriate for a particular learning goal are acceptable as long as the learning experience centers on scientifically oriented questions that engage students' thinking (NRC, 1996; Olson & Loucks-Horsley, 2000).

A common pedagogy for teaching and learning science by inquiry is the learning cycle approach. The learning cycle can be traced as far back as the late 1950s to the elementary school science curriculum project, Science Curriculum Improvement Study (SCIS) (Atkin & Karplus, 1962). It is based upon work by cognitive psychologists such as Piaget (1970) and has been demonstrated to model how humans construct knowledge (Lawson, Abraham, & Renner, 1989). In its original form, the learning cycle consisted of three stages: (1) exploration, (2) invention, and (3) application (Atkin & Karplus, 1962). The learning cycle approach has since been modified into versions such as the 5 E Learning Cycle (*Science for Life . . .*, 1992), 7 E Learning Cycle (Eisenkraft, 2003), and the Metacognitive Learning Cycle (Blank, 2000).

At its core, the learning cycle asks the instructor to do the laboratory activity (the exploration stage) first and the "lecture" (the invention stage) second. While this appears to be a simple adjustment in the traditional laboratory/lecture format to most science classes, in practice, it is very difficult and usually counter-intuitive for teachers to accept because many have never experienced learning for themselves in this way. In the 5 E Learning Cycle, the first E, engage, leads students to think about the prior knowledge that they have with a topic. In this stage, students also develop an interest in the topic so that they are motivated to investigate. The teacher may use various strategies in this section but will ultimately end with an explorable question that is used to focus the next stage. The question may arise from the teacher, the students, or as a collaborative effort from both. The source of the question and the development of the actual planning of the inquiry determines whether the investigation that follows is termed guided inquiry (teacher-generated questions) or full, open inquiry (student-generated questions). The next stage, explore, centers on the students' opportunity to gain firsthand experience with the science phenomena by interacting with materials, fellow students, and the teacher. Students conduct the investigations in order to answer the explorable question. This stage is followed by explain in which the teacher helps the students to move from the concrete experiences to a deeper understanding of the phenomena. This is in contrast to traditional teaching in which the explanation is taught before the firsthand experience. The next stage, extend, gives students an opportunity to connect the science content to other applications—especially to real-life situations. Evaluate, the fifth E, is the ongoing assessment of each stage to determine students' understanding.

Numerous studies have concluded that teachers teach as they were taught (Borko & Putnam, 1996; Bryan & Abell, 1999; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Zeichner & Tabachnick, 1981). Teachers, especially beginning teachers, often implement practices they have experienced as students, regardless of the effectiveness of the method, simply because the method is familiar.

A substantial body of work demonstrates that students of all ages and abilities increase understanding of science concepts and skills using the learning cycle approach. Lawson (1995) summarized a great deal of this research. Briefly, this pedagogical approach has been shown to . . .

- result in greater achievement in science and overall academic achievement (Renner et al., 1973).
- lead to better understanding of scientific concepts (Barman, Barman, & Miller, 1996; Marek, Cowan, & Cavallo, 1994) at the elementary through college levels (Allard & Barman, 1994).
- improve generalizable reasoning ability (Renner et al., 1973).
- increase initial understanding of science concepts when used as a text-based format as compared to traditional text passages which generally introduce terms before exploration of examples (Musheno & Lawson, 1999).
- improve students' attitudes towards science and scientific inquiry (Brown, 1996).
- develop students' process skills (Renner et al., 1973).

In addition to the research on the effect of this approach on student learning, additional research has been conducted that focuses on teacher use of this pedagogy. Marek, Eubanks, and Gallaher (1990) found that teachers who possessed a strong understanding of the Piagetian developmental model of intelligence and the learning cycle were more likely to effectively use learning cycle curricula. Interestingly, the instructor's skill in using the learning cycle approach is significantly related to gains in student reasoning skills (Benford, 2001). Settledge (2000) found that there is not a relationship between learning about the learning cycle approach and preservice teacher anxiety about science or teaching science. In order to maximize the effectiveness of this approach, all stages of the learning cycle must be included since each plays a special role in learning (Abraham & Renner, 1986; Renner, Abraham, & Birnie, 1985, 1988). We were unable to find any studies that examined the link between teacher content knowledge and use of the learning cycle approach.

Importance of Science Content Knowledge

It has long been a concern that elementary school teachers have weak backgrounds in science preparation and limited knowledge of science content. Guidelines for science education for preservice teachers have been in place since the 1970s (AAAS, 1993). In the 1980s, the National Science Teachers Association (NSTA) found that many colleges and universities were not following the recommendations and began the development of the NSTA (1983) guidelines for elementary science programs. In an effort to improve science teaching at the elementary level, two of the guidelines specifically address the science content preparation of preservice elementary teachers: Standard I.a states that all preservice elementary teachers should take 12 semester hours of laboratory or field-based science courses across biology, physical science, and earth science, and Standard I.b states that courses should be designed specifically to serve the needs of preservice teachers by addressing science knowledge for K-6 application, by increasing the skills in the processes of science for preservice teachers, and by developing positive attitudes towards science and science teaching.

The *National Science Education Standards* (NRC, 1996) also take a very strong position on the issue of science preparation for elementary teachers. Recommendations include (1) helping teachers to develop a more accurate understanding of scientific inquiry and what scientists actually do; (2) having experiences "to learn science through inquiry, having the same opportunities as their students will have to develop understanding" (p. 61); and (3) broadening preservice teachers' understanding of science through the use of research literature, technology, and collaboration with others.

These organizations have put forth strong recommendations for science content preparation because much research has been conducted with preservice elementary teachers that shows a lack of conceptual understanding with many common science topics. For instance, Ginns and Watters (1995) found only 37% of 321 preservice teachers had scientifically acceptable explanations for ice floating in water, 54% for a boat floating in saltwater vs. freshwater, 11% for atomic weight, and 35% for air pressure. Stepans, Beiswinger, and Dyche's (1986) results were even more dramatic. Only 2% of the preservice teachers they surveyed had scientifically acceptable explanations for the sinking and floating of wooden objects, 0% for the sinking and floating of metal objects, and 4% for the sinking and floating of clay objects.

Because of these and other concerns, the No Child Left Behind Act of 2001 (2002) states that teachers must be "highly qualified" to teach the subjects that they are assigned to teach. The Michigan Department of Education (2003) defines "highly qualified" for elementary (generalists) teachers as having a bachelor's degree, state certification, and passage of the Michigan Teacher Test for Certification (MTTC) Basic Skills and Comprehensive Elementary Exams. In Michigan, elementary credentials are issued for grades K-8. If a Michigan elementary teacher wants to teach in a specific content area in grades 6-8, in addition to fulfilling the generalist requirements, new teachers need to pass the MTTC exam in their subject area.

In most states, teachers are expected to teach certain subject area standards and benchmarks. This focus on teaching to standards is not likely to decrease in the future due to the No Child Left Behind legislation. Under this legislation, "states are required to establish their own annual tests aligned with state standards for grades three through eight to measure how successfully students are learning what is expected by the standards" (U.S. Department of Education, 2003b). The science content standards need to be in place for each state by 2005-2006. Beginning in 2007, the state science tests will measure students' progress in science at least once in each of three grade spans (3-5, 6-9, 10-12) each year (U.S. Department of Education, 2003a).

Research Hypothesis

Based upon this body of research, we propose that science content knowledge will have an effect on the ability to design an inquiry-based science lesson. This is not to say that there is a linear or hierarchical relationship between these two constructs. Designing inquiry lessons is more of a multifaceted process than designing a didactic lesson since it requires that teachers are flexible enough in their content knowledge to meet the possibilities that arise from open-ended inquiry. As a result, there are probably multiple factors responsible for the type and quality of lessons designed by teachers. While we recognize this complexity, we are focusing our study on the impact of content knowledge alone on the ability to design an inquiry lesson.

Method

Program Context

Research was conducted at a medium-sized urban commuter public university in the Midwest. At the university there are over 800 undergraduate elementary education students enrolled in the School of Education (SOE). Approximately half of the students transfer to the SOE from local community colleges, usually as a sophomore or junior. The entering ACT composite score for all non-transfer students in this study was 21, and the quartile distribution of ACT scores is comparable to national scores for college students who earn education degrees.

The elementary education program underwent significant changes in the fall of 2000. In the new program, all elementary education students were required to take 17 credits of science education courses. The program revisions were developed in response to policy recommendations made in the National Science Education Standards (NRC, 1996), *Project 2061: Science for All Americans* (AAAS, 1993), and the Michigan Curriculum Framework Science Benchmarks (Michigan Department of Education, 2000a). The current, reformed elementary science education program includes a course that focuses on the nature of science and science process skills, three science content courses, as well as a science methods course and a science capstone course. The science content courses, all with the title Learning by Inquiry, were created to replace the former requirements of large, traditional, lecture-based, non-majors science courses. The Learning by Inquiry courses were developed over a span of one year by a team of science educators and scientists and focused on students learning science content using a learning cycle approach. The courses, Learning by Inquiry: Physical Science, Learning by Inquiry: Earth/Planetary Science, and Learning by Inquiry: Life Science, were originally co-taught by a scientist and a science educator and are now primarily taught by scientists. This initial co-teaching experience enabled the science faculty to be mentored in the new experience of teaching with an inquiry approach. While the focus of these courses is the learning of science content, the instructors work to make the inquiry methodology explicit so as to model reformed teaching and to help the students construct links between content and pedagogy and develop more robust pedagogical-content knowledge (Shulman, 1986).

A major goal of the final two courses in the sequence is to integrate science content and pedagogy more completely. The science methods course focuses on the teaching of inquiry-based science. Because the content courses are taught using the inquiry approach, more time can be spent in the methods course reflecting on inquiry methodology and understanding how learning occurs more with inquiry-based science than in most traditional methods courses, which often have to provide content area instruction that models inquiry pedagogy. Preparing students to be thoughtful, knowledgeable, and confident teachers of science is the central aim of the course. In this class, the students write, reflect on, and teach learning cycle lessons which culminate with the creation of a science unit based on inquiry teaching and learning. Students are required to peer teach inquiry lessons in class, teach at least one additional lesson in a local K-8 classroom that connects with the local school curriculum, and assist with two other lessons. The cooperating teachers are selected based on prior experience with the program and on their use of inquiry teaching in their classrooms. The current research focuses on students enrolled in this methods course.

The final course, science capstone, requires students to look outside of disciplinary boundaries in science by asking them to integrate and expand beyond the material covered in all of the other courses and to become a member of a larger community of learners/teachers through action research. Each term the course is structured around one of the "big ideas" or unifying themes defined by the AAAS (1993). Students engage in learning cycle activities related to the "big idea" and also engage in action research in local schools, a practice viewed as critical to the development of effective teachers (Carr & Kemmis, 1988; Noffke & Stevenson, 1995; van Zee, 1998). The action research project consists of the preservice teachers pre-assessing elementary students, planning lessons based on the data collected, teaching two inquiry-based lessons, post-assessing students, and reflecting on the learning and teaching process. The goal of the action research project is to bring together integrative science content, inquiry-based pedagogy, and reflective practice in one activity.

Although we are fortunate to have such a robust set of science education course requirements, we encounter the same problems as other teacher education institutions that educate elementary education generalists. For example, as is typical for most elementary education preservice programs, a majority of our students do not have an intense interest in science. This lack of interest in science is apparent as slightly less than 10% identify themselves as science majors. The elementary education program requires both an academic major and minor area of study. Excluding those students who are focusing on early childhood education, the fields of study available for majors and minors for the elementary education students are (1) language arts, (2) math, (3) science, and (4) social studies. Students must earn a minimum of 36 semester hours in a major area and 24 semester hours in the minor area, except for math, which requires 30 semester hours for a major and 20 semester hours for a minor.

Study Design and Sample

This study represents a first step in the evaluation of the current reformed science education requirements. Valid data were collected from 234 students in the elementary education program who completed the elementary science methods course between 2000 and 2003. Generally, students take the methods course within a year of their student teaching (95% in this sample). The age at of the students in our sample ranged from 21-55 years, with the mean age at nearly 28 and the median age at 25. Over half of the students were nontraditional, that is, age 25 or over. The gender and diversity of our sample is typical of other populations of elementary education students. Eighty-nine percent of the students identify themselves as white, non-Hispanic, and 92% are female.

Students were informed about the evaluation project and gave consent when they enrolled in their first science course. Data were collected from the participating students during the semester in which they were enrolled in the science methods course. Measures included an inquiry lesson plan score and the test score on the released items from the Michigan Educational Assessment Program (MEAP) 11th Grade Model Assessment in Science (Michigan Department of Education, 2000b).

Inquiry-Based Lesson Plan Score

In this study, teacher behavior is measured as the *ability to create* an inquiry-based science lesson following the 5 E Learning Cycle of engage, explore, explain, extend, and evaluate (*Science for Life . . .*, 1992). We hypothesize that being able to create an inquiry-based lesson plan is a part of the foundation for being able to teach an inquiry-based lesson. Our hypothesis is based upon research that demonstrates that teacher content knowledge affects instruction (Borko, Bellamy, & Sanders, 1992; Grossman, Wilson, & Shulman, 1989; Smith & Neale, 1989). Students in our program have many opportunities to experience inquiry learning with the learning cycle approach first as a student in the science content classes and then as a preservice teacher in the methods course. The learning cycle, which is explicitly used to varying levels in the science content courses, requires students to be cognitively engaged in the concept they are to learn by exploring possible answers to a question and then, facilitated by the instructor, arriving at an understanding of the scientific concept. Next, students explore a related question designed to assess their ability to apply their new knowledge in a different context. The science methods course helps students to think about inquiry-based science from a teacher's perspective. The students practice critiquing and adapting sample activities in order to understand each phase of the 5 E Learning Cycle. They also practice writing sample learning cycle lesson plans and micro-teaching these to their classmates and elementary school students. The authors have noticed that students enrolled in the science methods course often make references to the pedagogy (and specific lessons) they experienced in the Learning by Inquiry science content courses.

The inquiry-based lesson plan score is based on the student's midterm exam score from the science methods course. The primary course instructor has taught the methods course for more than two decades and has used an inquiry-based lesson plan following the 5 E Learning Circle format for the midterm exam since 1986. In this 90-minute exam, each student selects a science activity from a traditional elementary school science text to use as a basis for a lesson plan. Students are allowed the use of the textbook during the exam since many schools use a textbook as a basis for the district curriculum. Students adapt the selected activity so that it is changed from a directed, follow-the-directions type of activity, to an inquiry-based lesson plan which follows the 5 E Learning Cycle Lesson Plan. The exams are scored using a rubric, a method the students are familiar with from previous experiences writing inquiry-based lesson plans in the methods course (Table 1).

Each stage of the 5 E Learning Cycle Lesson Plan is assessed for congruence with the learning cycle as well as accurate science content.

Internal validity was established with two instructors of the science methods course. Together, they have 38 years of experience teaching science methods and learning cycle pedagogy. Thirty midterm exams were randomly selected for scoring for validity purposes. Each instructor followed the established rubric to score the exams (Table 1). An Alpha (Cronbach) model was used to calculate the average correlation between the two scorers. This analysis revealed an average agreement of .80, which we accepted as adequate for the purposes of this study.

Table 1
Learning Cycle Lesson Plan Rubric

Possible Points	Learning Cycle Phase	Instructor Comments	Points Earned
3	Lesson objectives, concept(s), benchmark(s), safety issues, etc.		
5	Engage—It must focus on an explorable question.		
5	Exploration—It must provide some type of an Inquiry activity which will answer the question.		
5	Explain—Concepts introduced here must be developed based on the exploration.		
5	Extend/apply		
3	Evaluate—Only performance assessments earn all 3 points, and they must match the stated objective of the lesson.		
Total possible: 26 points			

Michigan Educational Assessment Program (MEAP)

Science content knowledge was measured by a model test that was composed of released items from the eleventh-grade state science test, the MEAP (Michigan Department of Education, 2000b). The MEAP is composed of multiple-choice and constructed response questions based on the Michigan Curriculum Framework and Benchmarks. We believe this is an appropriate assessment of science content for elementary education students who eventually must teach the same objectives. The MEAP test is the only common measure given statewide to all students and serves as a measure of accountability for Michigan schools. Michigan's MEAP tests are criterion-referenced; the standards are set by Michigan educators and approved by the Michigan State Board of Education. Test reliability and validity have been established through accepted procedures which are described at the Michigan Department of Education (2001) website.

Results

Data were analyzed using *SPSS Version 11.0.1.* The average score on the MEAP was 41.1 (n = 234, SD = 7.3). The scores ranged from 14 to 58 correct. The highest possible score on the model assessment that we used was 62. For the inquiry lesson, the average score was 18.6 (n = 244, SD = 4.2) out of a possible 26 points. Scores on the inquiry lesson plan varied from 6 to 26.

Our research question, "What type and to what level of sophistication of science content knowledge is a prerequisite to designing inquiry-based science lessons?" was answered by calculating a bivariate correlation between our science content measure, the overall MEAP score, and the inquiry lesson plan score. While correlations do not describe causality, they do identify if there is a relationship between two variables. In this case, a correlation would indicate if there was an association between the ability to write an inquiry-based lesson plan and science content knowledge. A two-tailed Pearson correlation showed that there was a significant positive relationship between content knowledge and ability to create an inquiry-based science lesson ($r(234) = .33$, $p = .000$).

The strength of the relationship was also identified by calculating the square of the correlation coefficient, r^2. This measures how much of a change in a student's ability to write a lesson plan is accounted for by a change in science content knowledge. This measure of common variance, r^2, is 11%. Not surprisingly, other factor(s) besides science content knowledge account for much of a student's ability to write an inquiry lesson plan. To investigate the relationship further, we compared the lesson plans of students with low MEAP scores to the lesson plans of students with high MEAP scores. There was not a difference in number of science misconceptions present. Both sets of students had few misconceptions present in the plans.

We also were interested in knowing how students developed their content knowledge. Were students with more traditional science courses better able to design an inquiry lesson than students with the inquiry courses? We compared midterm scores of elementary science majors with other elementary majors and did not find a significant correlation. We concluded that simply taking more traditional science courses (and presumably increasing one's content knowledge) did not improve the students' ability to create an inquiry lesson plan. Next, we investigated if the knowledge was correlated more to the traditional science courses or to the newly reformed inquiry-based science content courses. There was a significant positive correlation between the number of inquiry-based science content courses and midterm scores ($r(244) = .14$, $p = .026$). Students who took all three inquiry-based courses scored 2.5 points higher on the midterm than students who took only traditional science courses. This represents nearly a 10% increase in lesson plan score. Apparently, some factor besides increased content knowledge present in the inquiry courses helps students develop inquiry lesson plans.

While we were not able to directly identify what aspect of the inquiry courses led to an increased ability to design an inquiry lesson, an analysis of the MEAP subscore correlations and midterm scores revealed a potential answer. Aside from the overall score which was significantly correlated, the subscore for the section on constructing new scientific knowledge was significantly and most strongly correlated to the inquiry lesson score ($r(233) = .300$, $p = .000$). This section from the Michigan Curriculum Framework includes the standards of (1) generating scientific questions about the world; (2) designing and conducting investigations; (3) using tools, equipment, and measurement devices; and (4) constructing charts and graphs to communicate findings. The benchmarks within constructing new knowledge are directly related to different stages of the 5 E Learning Cycle Lesson Plan: knowledge of the first standard is necessary to create an explorable question, the second standard relates to the inquiry activity in the explore stage of the learning cycle, and the third and fourth standards are incorporated into both the explore and extend stages.

While life science and physical science content area knowledge was significantly correlated ($r = .211$ and $r = .249$), respectively, and therefore contributed to the ability to design the lesson plan, the ability to *construct* knowledge was most correlated with the ability to *construct* an inquiry lesson. This finding enabled us to identify what level of sophistication of science content knowledge is required. More than disciplinary knowledge is needed; inquiry content knowledge is also necessary. The National Science Education Standards define inquiry as one of the eight areas of science content that requires students to "combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science" (NRC, 1996, p. 105).

Discussion

The data show that there is a relationship between the type of science content knowledge and the ability to design an inquiry lesson. Students who had not completed any of the newly reformed inquiry science classes were not as a group as competent on writing inquiry lessons as the group of the students who had completed one or more inquiry courses. We believe that this is because students had experienced inquiry for themselves, many for the first time. Scientists who taught the inquiry courses modeled teaching as facilitating scientific understanding rather than teaching as giving out facts and information. Students were able to experience "science through inquiry, having the same opportunities as their students will have to develop understanding" (NRC, 1996, p. 60). We believe that this is also supported by the significant correlation of the MEAP subscore on the section of constructing new scientific knowledge. Since the students in the inquiry classes experienced those standards many times throughout the course(s), they were able to demonstrate their understanding of inquiry on that section of the MEAP. Students who had only taken traditional science courses in college typically did not get many opportunities in science labs to ask questions and design investigations for themselves.

We recognize that there may be other possible reasons for the correlation. Very few students with limited content knowledge were completely successful in creating an inquiry-based lesson plan. In some cases, no inaccurate science knowledge showed up on the plans, but the students were unable to modify the content from a traditional format to inquiry. This could be due to several factors. Lack of depth of knowledge or lack of flexibility in the knowledge (such as the ability to transfer knowledge to similar contexts), or a lack of understanding of the learning cycle format are possible reasons for the limited ability to create the lesson plan.

Since students chose the science concepts for the lesson plans, they probably selected a topic with which they were confident. If they understood it correctly, it would decrease the number of misconceptions present in their midterm lesson plans. Only by copying the content incorrectly from the text into the explanation stage of the lesson plan were they likely to have a misconception in their lesson plan. This would increase their lesson plan score regardless of the actual level of their overall science content knowledge. This raises the issue of how do we measure student self-confidence? Perhaps confidence accounts for some amount of the ability to construct a learning cycle lesson. We suspect that confidence is related since we often hear students state that the reason that they chose the topic of their science unit was because they felt confident in knowing the content associated with that topic.

Another possibility is that an unidentified third factor is simultaneously influencing both content knowledge and lesson planning ability. This unknown variable might be a more complex factor such as pedagogical content knowledge or the anxiety produced because the lesson plan was created during an exam. One way to determine if the test setting had an impact on the lesson plan would be to evaluate the unit lesson plans that the students create at the end of the semester; however, these final course products reflect the influence of the methods course instructor more so than does the midterm exam.

Further studies are needed to determine what other factors (i.e., type and amount of science courses taken, demographic factors, pedagogical content knowledge) are responsible for the ability to create an inquiry-based lesson. In the future, we also need to determine if students realize their lack of understanding(s) as they prepare inquiry lessons. Is their awareness of their lack of content knowledge different when preparing lower-level, didactic, vocabulary driven lessons than when creating inquiry-based lessons? It would also be useful to repeat the study using another state's assessment (i.e., the Praxis) to compare the results with the MEAP. Additional studies could examine how the ability to write inquiry lessons (if possessed) is translated into classroom practice. We are currently observing and evaluating the practice of our student teachers using the Reformed Teaching Observation Protocol (RTOP) (Piburn & Sawada, 2000). The RTOP determines the extent to which a teacher uses "reformed" (inquiry-based) pedagogy.

These results demonstrate again the importance of content knowledge. A unique aspect of this study is that the content knowledge assessed is directly from the state standards, and the outcome measure is the ability to construct a 5 E learning Cycle Lesson Plan. The state standards represent the content that the preservice teachers will have to teach. Further, a correlation has been established between these basic understandings and the ability to create an inquiry-based lesson plan. The authors recognize that designing inquiry-based lessons is a complex process. Science content knowledge, however, is fundamental. We recognize as well the importance of other factors that contribute to the ability to construct inquiry-based lessons in science. This study has explored the relationship between two variables—science content knowledge and inquiry-based lesson planning skill ability—that we consider critical to the realization of the goals of professional and governmental agencies.

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Correspondence regarding this article should be directed to

Gail Luera
School of Education
Science Education, Fairlane Center
University of Michigan–Dearborn
19000 Hubbard Drive
Dearborn, MI 48126-2638
(313) 593-5090
grl@umich.edu

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