

Is Inquiry-Based Instruction Good for Elementary Teaching Majors? The Effects on Chemistry Content Knowledge and Views About Teaching and Learning Science

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Abstract. Although science educators have advocated that elementary teaching majors learn science concepts using inquiry-based methods, many college professors believe that these courses are merely “watered down” versions of traditional lecture-based courses. This study compared the chemistry content knowledge of elementary teaching majors enrolled in an inquiry-based course and science majors enrolled in traditional lecture-based courses. It also compared the elementary teaching majors’ views of how science is taught and learned to the views of secondary science teaching majors. The elementary teaching majors developed chemistry content knowledge comparable to the students enrolled in the traditional lecture-based course, but they developed views regarding how science is taught and learned that were more in line with the constructivist ideals than the secondary science teaching majors. The elementary teaching majors also improved their interest and confidence in teaching science in the elementary school setting. These results suggest that both sets of teaching majors would benefit more from inquiry-based science courses than lecture-based courses.

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INTRODUCTION

The use of inquiry-based instructional methods in the science classroom (both K-12 and beyond) has been widely advocated from a variety of sources including national standards for K-12 teaching [1, 2], national reports on the crisis in K-12 mathematics and science education [3, 4], and editorials and commentaries from science education journals [5-8]. These methods have also been advocated for college chemistry courses for teachers, especially elementary teachers. Reasons cited for this suggestion include the ideas that what students learn and how they view science are greatly influenced by how they are taught [1, 9, 10], that teachers tend to teach using the same methods and in the same ways they were taught [1, 5, 11, 12], and that teachers with poor science content backgrounds tend to feel underprepared and thus avoid teaching science to their students [10, 13-16].

While these recommendations tend to focus on the use of inquiry-based methods as a way to improve students’ science content knowledge, they fail to take into account one of the major strengths of inquiry-based methods—their potential to affect students’ perceptions of what science is and how it is done, and more importantly for future teachers [17, 18], how

science is taught and how it is learned [1, 2, 9, 10]. Piaget’s theory of cognitive development [19-21] and the constructivist theory of knowledge [22, 23] support the notion that inquiry-based lessons should improve students’ content learning and their views about teaching and learning science. However, many college professors view inquiry-based courses as “watered down” versions of traditional lecture-based courses that will lead to inferior learning.

This study is concerned with two research questions: (1) Do students learning chemistry using different instructional methodologies develop comparable chemistry content knowledge? and (2) How are students’ beliefs regarding how science is taught and learned different for students learning chemistry using different instructional methodologies?

METHODOLOGY

Subjects

The elementary teaching majors ($N = 16$) in this study were junior and senior preservice elementary teaching majors enrolled in a physical science course taught using inquiry-based methods. This course was a one-semester four-credit (five-hour per week)

chemistry and physics content course intended for elementary teaching majors based on learning cycles [24] with minimal lecturing and most of the class time spent in the laboratory setting. The experiments were specifically written so that they could be adapted to the elementary science classroom, and involved equipment and chemicals that could be purchased at supermarkets, toy stores, or hardware stores. Prior to this course, these students had completed 2-4 science content courses using similar inquiry methods.

The chemistry content knowledge of the elementary teaching majors was compared to that of students enrolled in general chemistry courses taught by the same instructor. This comparison group was used because elementary teaching majors who did not take the physical science course were allowed to use this chemistry course (or the equivalent general physics course) as a substitute. These students were primarily freshmen majoring in natural science (biology or chemistry). This course was structured in the traditional format, with three hours of lecture and one three-hour laboratory per week.

The elementary teaching majors' views of teaching and learning science were compared to the views of junior and senior secondary science teaching majors enrolled in science methods courses ($N = 24$). Many of these students were planning to teach chemistry in grades 7-12, and all of them had completed several traditional lecture-based college science courses, including the general chemistry courses.

Data Analysis

For the comparison of chemistry content knowledge, both sets of students were asked to answer the same chemistry content question after receiving very different instructional lessons on the same topic. The content questions were conceptual in nature and covered five topics in chemistry: Density; compressibilities of solids, liquids, and gases; the structure of an ionic solid; surface area and evaporation; and the immiscibility of oil and water. For each question, students were given one point when they provided a correct response and when they did not demonstrate a misconception, for a total of two points. Statistical comparisons of the two groups' responses were made using the Student's t distribution or a statistical test of proportions [25].

To compare the students' views on teaching and learning science, written reflections from their class assignments were analyzed. The elementary teaching majors were asked to discuss how they would adopt the experiments for elementary students, what worked well in the experiment and what did not, and any questions or concerns they may still have regarding the

material covered in these experiments. The secondary science teaching majors provided reflections based on their perceptions of what makes a good science teacher, what the ideal science classroom would look like, the instructional methods that they liked/disliked and with which they learned the best/worst, and their observations and experiences in actual secondary science classrooms. The reflections were analyzed to identify differences in students' beliefs regarding the way chemistry is taught and learned, and according to the instructors who have taught these courses the categories identified from these reflections describe real differences between these two groups.

RESULTS AND DISCUSSION

For four of the five chemistry content questions, there were no significant differences between the responses of the elementary teaching majors and the natural science majors (all $p > .05$), and the percentage of students providing a correct response or demonstrating a particular misconception were similar for the two groups. In all cases, the scores for the elementary teaching majors were slightly higher than those of the science majors. The similarity of the responses between the two groups can be seen in the following responses to the ionic solid question: 'Describe the forces holding a crystal of sodium chloride together'.

"The Na^+ ions are attracted to the Cl^- ions. The attraction of '+' to '-' is very strong. The '+'/'+' or '-'/'-' repulse each other, but the '+' and '-' hold strong together." [*Natural science major*]

"The + want to be with the - and as far away from the other + as they can. The - want to be with the + and as far away from the other - as they can. This attraction keeps them together." [*Elementary teaching major*]

For the conceptual density question ('Explain the concept of density at the molecular level without using the words *mass* or *volume*.'), the difference between the students' responses was significantly different ($t_{46} = 2.12, p = .04$). The elementary teaching majors were more likely to describe density in terms of the 'crowdedness' or 'closeness' of matter, and were less likely to use alternate words for *mass* (like *weight* or *heaviness*) and *volume* (like *space* or *area*) or provide a mathematical definition.

These results suggest that the inquiry-based physical science course helped the elementary teaching majors learn chemistry content at least as well as (and perhaps a little better than) a traditional

lecture-based general chemistry course. This is in direct contradiction to the notion that hands-on chemistry lessons are somehow “watered down” versions of the lessons presented in traditional lecture courses [26, 27], and should provide convincing evidence that inquiry-based instructional methods can be used to develop students’ conceptual understanding of science concepts.

Eight topics related to the teaching and learning of science (in which the two groups of students held different beliefs) were identified from the students’ written reflections; a summary of these ideas appears in Table 1. The ideas expressed by the elementary teaching majors who studied science using inquiry-based methods were more mature [17, 18] and were more consistent with constructivist ideals [22, 23] than those of the secondary science teaching majors who studied science in traditional lecture-based courses. In particular, the elementary teaching majors viewed chemistry as an explanation of nature based on empirical evidence collected as part of their studies, while the secondary science teaching majors viewed chemistry as a set of unrelated facts that were blindly accepted from the “experts” (teacher or textbook).

In addition to demonstrating more constructivist ideals regarding the teaching and learning of science, the elementary teaching majors in this study also showed remarkable interest and enthusiasm for teaching science, and confidence in being well prepared to teach science lessons to their future students as a result of the inquiry-based science courses they had taken. These students reported that performing these hands-on lessons involving real-world applications had greatly improved their interest and confidence in teaching science.

“When I was in high school I did not enjoy physics or chemistry... However, as it turns out chemistry and physics can be fun—imagine that! Your class really opened my eyes and made me realize that physical science can be fun and interesting—and messy! I no longer hold on to those bad memories of high school chemistry of balancing equation after equation. Now I know that chemistry can be fun and interesting for both my students and I.” [*Elementary teaching major*]

“I know that this course has affected me because I have seen my new found knowledge shine through in an actual classroom. I went to Grant Elementary to teach a light lesson right after we had talked about colored light. I was quite nervous worrying that I would ‘mess’ up or not be able to explain everything correctly. The knowledge that I learned from only a few days of class had made me extremely confident that day in the classroom. My lesson went well and it made me feel that I was accomplishing something in classes—which does not really happen too often.” [*Elementary teaching major*]

The lack of meaningful science instruction in elementary schools has been generally attributed to the teacher’s lack of interest or enthusiasm for teaching science [10, 13, 15, 16, 26] or the teacher’s lack of confidence in their abilities to teach science effectively [10, 13-15]. These results suggest that the use of inquiry-based instructional materials not only improves the elementary teaching majors’ conceptions regarding the nature of science, but also improves their interest, enthusiasm, and confidence in teaching science concepts to their future students.

TABLE 1. Topics where the secondary science and elementary teaching majors had different views regarding the teaching and learning of science.

Topic	Secondary Science Teaching Majors’ View	Elementary Teaching Majors’ View
Role of the teacher in the science classroom	Teacher is the source of information	Teacher guides students to find information on their own
Role of the textbook in the science classroom	Textbook is the source of information	Textbook is a supplement to help students explain their observations
Teacher’s role in the science classroom	Teacher transfers knowledge (lectures) to the students	Teacher acts as guide to help students learn on their own
Role of lecturing in the science classroom	Primary (sole) method of knowledge transfer from teacher to students	Minimized (but not eliminated) in favor of hands-on instructional methods
Effect of feeling ‘lost’ or ‘out of control’ in the science classroom	Prevents learning because students are uncomfortable	Initial confusion is okay, and will disappear after more experiments
Effect of students making a mistake in the science classroom	Fatal, because students learn the wrong things	An opportunity to discuss experimental techniques, how science is done
Role of conceptual understanding in the science classroom	Unimportant, and gets in the way of learning facts and algorithms for tests	The goal of teaching science, and important
Role of outside experiences / “real world” in the science classroom	Unimportant, and gets in the way of learning facts and algorithms for tests	The goal of teaching science, and important

IMPLICATIONS FOR THE CLASSROOM

This study makes a strong case for the inclusion of inquiry-based methods in science content courses for preservice elementary teaching majors. The elementary teaching majors enrolled in this inquiry-based physical science course learned chemistry content knowledge at a level comparable to (if not slightly better than) students enrolled in traditional lecture-based courses. In addition, these students development more mature views regarding how science is done [17, 18], and how it is taught and learned, compared to secondary science teaching majors who studied their science content in traditional lecture-based courses. The use of inquiry-based methods in the science content courses for the elementary teaching majors also improved their interest and confidence in teaching science, two measures which are also directly tied to their science content knowledge. These results also suggest that we should use inquiry-based instructional methods in the content courses for secondary science teaching majors if we want to improve the way they view how science is taught and learned.

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