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What Do Preservice Teachers Learn in an Inquiry-Based Science Methods Course?

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Abstract

This study investigated how early childhood education (ECE) (PreK-3) preservice teachers' ideas about science education change as a result of implementing an inquiry-based curriculum within an ECE science methods course (ten-week quarter). Fifty-two preservice teachers, including 50 females and 2 males, with 2 members of an ethnic minority group were part of the study. The preservice teachers' knowledge and understanding of how to implement inquiry learning deepened over the ten-week period. The preservice teachers seemed to gain some confidence in implementing inquiry learning. Preservice teachers need to have focused science teaching time with primary students to strengthen and support their confidence, attitudes, and abilities to implement inquiry learning. Also, support for inquiry learning must come from K-12 educators as well as arts and science faculty, as this is where preservice teachers can develop substantive content knowledge within authentic science learning experiences.

Purpose

The purpose of this study is to investigate how (ECE) (PreK-3) preservice teachers' ideas about science education change over a ten- week quarter as a result of implementing an inquiry-based curriculum within an ECE science methods course.

Theoretical Framework

Engaging students in application of thinking and reasoning skills and the promotion of inquiry-based instruction has become the focus for many educators (Edwards, 1997; NSTA, 1998). The process of inquiry promotes the exploration of questions raised by both students and the teacher. When the inquiry process skills (i.e., observing, classifying, measuring, communicating, predicting, inferring, and experimenting) are connected with science content, students discover meaningful concepts and understandings (Llewellyn, 2002).

Research has shown that when students are challenged and engaged in their learning, they achieve success in education (Marx et al., 1994). An important part of this success comes from making learning real to students. Authentic learning allows students to be actively involved in solving real-world problems. The teacher, who is considered a facilitator, works with individuals or small groups of students. While making decisions about how to solve problems, knowledge, skills, and attitudes are developed in the context of meaningful experiences that

relate to the real world. Connections are continually made between experiences, which allows for easy carryover of knowledge, skills, and attitudes learned and employed from one context to the next.

These types of authentic learning experiences are achievable in regular classroom settings. Reasonable approximations can be created to offer students a quality level of engagement, meaning, and learning in the classroom.

Inquiry-Based Education and How It Relates to Understanding Science Concepts

Current efforts in science education emphasize the importance of the inquiry-based approach to teaching because it promotes deeper and more meaningful learning (NRC, 2000). Research within science education details how students who engage in the acts of exploratory investigations construct meaning from their findings, propose tentative explanations and solutions, and evaluate concepts in reference to their own lives are more scientifically literate than those students who learn through the use of direct instruction (Marx et al., 1994; Zuzovsky & Tamir, 1999). The ability to interact with the instructor, other learners, and materials has been shown to promote deeper meaning and understanding of new knowledge as well as develop higher-level thinking skills (Anderson, 2002). The inquiry-based approach requires preservice teachers to take responsibility for their learning. There is evidence from research in science education that preservice teachers value their education more when they are given the chance to articulate, test, share, and act on their ideas and findings (Bianchini & Solomon, 2002; Ramey-Gassert, Shroyer, & Staver, 1996).

Many of the experiences that PreK-3 preservice teachers have had in science involve the use of direct instruction, teaching in a way that does not involve the learner, which has been shown to be ineffective in promoting higher-order thinking (Dobey & Schafer, 1984; Rodriquez, 1998). Allowing preservice teachers to conduct their own independent inquiries and connect their experiences with strategies for using inquiry in their own classrooms is a promising approach for science methods instructors (Hand & Peterson, 1995; Stofflett & Stoddart, 1994). As designing effective teacher development curriculum is a continuing challenge to science teacher educators, there is a need to investigate the impact of preservice teacher methods courses on preservice teachers' understanding of inquiry (Cobern & Loving, 2002). This study will examine how ECE preservice teachers' ideas about science education change over a ten-week quarter as a result of implementing an inquiry-based curriculum within an ECE science methods course.

Course Setting

The methods course encompassed the following items:

- Goals and objectives in teaching science that connect with the *National Science Education Standards* (NRC, 1996)
- A field trip to an internationally renowned zoo that focused on how to use the science process skills
- In-class discussions on the nature of science and included readings from a methods textbook (Abruscato, 2004)
- Lesson and unit planning assignments (Includes Bloom's Taxonomy and the Five *E*s—engage, explore, explain, elaborate, evaluate)

- Demonstrations and experiments in physical science (rocket launcher), earth science (Moh's hardness scale, identification of different rocks and minerals, soil testing and water experiments), and life science (plants)
- Guided and independent inquiry projects with butterflies (types of food and environment), crustaceans (crayfish-territory), and plants (temperature, light/dark, amounts of water, types of soil, etc.)
- Integration of other subject areas (e.g., math, language arts, technology)
- Assessment (development of rubrics and checklists for course assignments, lesson and unit plans)
- Inclusion of the science process skills in all aspects of science teaching
- Implementation and evaluation of Full Option Science System (FOSS) kits

As the course is to serve as a model for how research has shown that PreK-3 students should experience science, the following course goals were established:

- Increase confidence in science knowledge and process needed for teaching elementary science.
- Encourage role as "guide on the side" or facilitator.
- Diminish reliance on lecture, worksheets, and textbooks.
- Promote learner-centered projects.
- Establish a support network with peers.
- Focus on inquiry-oriented, project-based learning.
- Integrate technology, mathematics, communication, and language arts into science inquiry projects.
- Value a direct experience with the natural world.
- Promote the use of collaboration with the community.

Methodology

In the fall of 2003, a cohort of 52 undergraduate students, 50 females and 2 males, with 2 members of an ethnic minority, was enrolled in the fourth quarter of their six-quarter teacher education program. The students were completing a student teaching experience during the same quarter. Preservice teachers' ages ranged from 21 to 34 years with the median age of 24. The complexity of preservice teachers' understanding of the science inquiry process required the use of multiple data sources. Thus, all preservice teachers were given pre- and post-questionnaires on the inquiry process.

Data Sources

In the following section, the teaching methods used to promote inquiry-based science are described. Within the course, there was a focus on guided and independent inquiry. Through guided inquiry, the students were provided a problem to investigate for which they had to find a solution. Through independent inquiry, they developed their own questions and designed their own investigations. Some structured inquiry in which they were presented a question and a specific procedure to follow was also emphasized. Mastropieri et al. (1998) describe inquiry instruction as a useful tool that allows all students to learn science. Preservice teacher participation in the following activities formed some of the data sources for the study into how their ideas change as the result of implementing an inquiry-based curriculum. The data collected from these course activities was compared,

allowing for emergent themes to develop through the use of triangulation of data (Patton, 1990).

Pre- and Post-Questionnaire

Students answered the following open-ended questions on the first and last day of the science methods course. They were given time in class to complete their answers.

- How do you define inquiry learning?
- How does inquiry learning relate to science?
- What are the pros and cons of inquiry learning?
- How do you see your own personal style of teaching relating to inquiry learning?
- What do you see as the type of learning that takes place when you focus on inquiry?
- Is it possible for students to learn through the use of science projects? If so, what do they learn?
- Do you think you will use inquiry learning when you teach? If so, how do you see yourself using inquiry-based education?

Journals

The preservice teachers maintained a journal in which they recorded written reflections on class discussions, inquiry lessons, and a field trip to the zoo that included an independent inquiry question, peer-teaching, chart of animal and plant change over time, and how these activities would inform their own future teaching. The journals allowed the preservice teachers to examine their own beliefs in relation to the inquiry process (Jorgeston, 1994). Journal prompts (e.g., "How would you engage students in observing or comparing objects using inquiry-based methods? What does teaching with inquiry-based methods look like?") were given to help guide the preservice teachers.

Science Lesson

The preservice teachers wrote and taught a lesson in their field practicum placements, which included first, second, or third grade classes. In relation to data collection, the focus was implementation of the science process skills and how they were embedded in the lessons, higher-order questions, connection to science literature, Predict-Observe-Explain (POE) (White & Gunstone, 1992), and assessment that ties to the objectives. Emphasis on Bloom's Taxonomy (1984) within the higher-order questioning was required. Inquiry was not required as part of the science lesson, though the preservice teachers were to try and include structured or guided inquiry procedures if possible. Each of these topics was modeled and discussed as a means of introducing specific science concepts. An outline of the science content being addressed was required within the lesson.

Field Trip

To practice the implementation of the science process skills, the preservice teachers went on a field trip to the local zoo. In class, they paired and discussed how

they would use the process skills during the trip. They were given approximately 30 minutes to talk about using observation, classification, measurement, communication, prediction, and inference during the field trip (they were unable to develop an experiment, as they couldn't manipulate variables). The preservice teachers were to focus on a particular animal and develop questions that could be answered using the science process skills. During the zoo visit, the preservice teachers spent time observing animal behavior and characteristics, eating habits, etc. They recorded information and data in their journals. Once back in the classroom, they discussed the information obtained through the use of the process skills and what impact the process skills would make on a field trip conducted with primary-age students. In relation to this article, the field trip is not an additional data source, as the information was included in their journals.

Data Source Categories

Categories were produced from the multiple data sources (pre- and post-questionnaire, journals, focus group interviews, and assignments) that emphasized the preservice teachers' emerging understanding of science and inquiry-based education:

- Personal aspects (e.g., parent influence, nonformal education, etc.)
- Methodology and curriculum issues (e.g., use of different teaching methods and perceived effectiveness, understanding science content and comfort level in teaching science, etc.)
- Societal/political concerns (e.g., covering the science curriculum, testing, etc.)

Data Analysis

A comparative analysis was completed on the preservice teachers' assignments (science lesson and journal, which included the field trip), pre- and post-questionnaires, student journals, and focus group interviews (Glaser & Strauss, 1967). The development of relationships between preservice teachers' ideas, reflections, and actions helped to establish trends within the data regarding inquiry (Miles & Huberman, 1984). Data coding began with a review of the responses to the pre- and post-questionnaire. Using the multiple data sources (pre- and post-questionnaire, journals, focus group interviews, and assignments), analysis produced categories that highlighted the preservice teachers' emerging understanding of science and inquiry-based education and how to apply these concepts to their own teaching. Analyzing assignments allowed for further branching of the categories to include personal aspects (e.g., parent influence, nonformal education, etc.), methodology and curriculum issues (e.g., use of different teaching methods and perceived effectiveness, understanding science content and comfort level in teaching science, etc.), and societal/political concerns (e.g., covering the science curriculum, testing, etc.). The majority of the data coding came from the pre- and post-questionnaires, science lesson, and journals as they provided most of the written text. The patterns that began to emerge from the preservice teachers' thinking about science and inquiry-based education included making science relevant for children and promoting critical thinking. These ideas were seen throughout the data and served to shape the preservice teachers' understanding of science teaching practices.

As the study's focus was to consider how the preservice teachers' views about inquiry-based science education changed over the course of the quarter, in the final coding, the focus was on their adoption and extension of course ideas and activities, development of questions or concerns about course content and strategies, and focus on their own insights into how to teach inquiry science. A foundation for the attitude change was laid when the focus group students were asked about their prior experiences with inquiry-based science education before the ten-week course. Also, on the first day of class, all of the students began their journals with questions that asked them to rate their attitude toward science education and inquiry-based learning. At the end of the quarter, students were again asked to rate their attitude toward science education and inquiry-based learning, which was included as one of their last journal entries.

Ten preservice teachers volunteered to participate in a focus group interview. Participation in the focus group interview was voluntary, but all course assignments were required. The volunteers received a letter stating that the study had no bearing on their course grade, and the study was approved through the Human Subjects Review. The focus of the interviews was to expand upon students' experiences with inquiry learning prior to the science methods course, what they learned about inquiry while in the class, and how they saw themselves emphasizing inquiry within their own teaching. Since questions similar to the pre- and post-questionnaire were asked during the interviews, the preservice teachers' answers were analyzed for differences. These interviews were mainly for confirmation of data that was already gathered from the questionnaires. All interviews were audiotaped and transcribed. No names were used when transcribing the interviews. Each student had an alias and was referenced by transcript line number. Categories and prevalent themes were developed based on the discussion trends and the use of science education research literature.

Findings

In the following section, responses to the research questions are presented. Data from multiple sources is used to highlight issues associated with each question.

Research Question 1: What ideas do preservice teachers have about science?

Examination of the pre-questionnaire indicated that students saw science as relating to a particular subject, such as chemistry or physics, with little to no overlap between the subject areas. Over half of the preservice teachers tended to perceive science as compartmentalized with little integration. Helen explained science education as "a way to learn about chemicals or rocks." Similarly, Rachel saw scientists as "experts in their own field who know a lot about their own area."

There was emphasis on how they learned science in previous courses, such as conducting prescribed experiments that had a known outcome. The desire to learn specific information for a test was also highlighted. They also focused on science as being clear-cut and matter-of-fact as illustrated in this explanation by Sarah: "Scientists find answers to all kinds of questions such as when dinosaurs were alive."

When describing science as a process, the preservice teachers focused on developing hypotheses and conducting experiments. They saw science education

as lab-based with a step-by-step process that should be followed. Samantha explained, "In high school, we used to set up experiments that had specific answers and we had to keep repeating it until we got the right answer."

A quarter of the preservice teachers felt that science education was essentially for prospective scientists and others wouldn't need science after a certain grade level, such as the early high school years. Amy saw science as "something you are either interested in or you're not. Why would you need to study it after a certain point?" In a parallel description, Andrea stated, "I never liked science and never felt the need to take more science classes."

After the ten weeks within the science methods course and being involved with inquiry-based projects, the preservice teachers showed an overall shift in their explanation of science. Based on their journals, post-questionnaires, and focus group interviews, almost all of the preservice teachers described a deeper understanding of science. Mary Beth stated, "You can create new knowledge about objects, etc., and questions can be answered through observation, exploration, and discovery." Similarly, Tracy said, "We can ask questions about things we are curious about and then investigate and find an answer, which may lead us to more kinds of questions."

Over 75% of the preservice teachers, however, still seemed to be unsure of who was in control of the learning process while teaching science. The shift from a traditional teaching approach in which the instructor is in control to a more self-directed learning approach was difficult for the preservice teachers. Courtney explained, "I like it when the instructor tells me what to do; I like the guidance and structure to the process. It is hard to be my own guide. I struggle with what to do next." Even though the students found the independence of the inquiry-based approach to be somewhat difficult, they found they had other supports, such as their peers, to help them.

Research Question 2: What observations and conclusions do preservice teachers make about their own knowledge, attitudes, and behaviors in relation to the inquiry-based approach within science?

Personal experiences that consisted of parent influence and nonformal education were brought up in the focus group interview. The preservice teachers who had positive attitudes about science prior to the science methods course related these attitudes to camping as children, nature hikes in parks, water sports, gardening, and having parents that worked in science-related fields. Mary Beth explained, "I grew up in a family that spent a lot of vacations camping in national parks. We hiked, swam, and fished together. I really enjoyed nature growing up and see it as an important part of my life." These personal experiences were very meaningful for the preservice teachers, and there was overlap between family experiences with science and those that took science classes in high school and college.

Past experiences with K-12 science education also had a powerful influence on how preservice teachers viewed inquiry learning. There were a few preservice teachers who had positive experiences in their previous science classes and felt positively about teaching inquiry-based education prior to the science methods course. These same preservice teachers also felt good about their knowledge of science content. Andrea explained, "I had a couple of great science teachers in high school and really got turned on to science. I think these experiences have a direct influence on my wanting to teach."

When focusing on their own beliefs in relation to the inquiry process that highlighted past experiences with K-12 science education, close to 80% of the preservice teachers' journal responses were not positive. Most preservice teachers described their previous experiences in science as "boring," "dry," or "lots of worksheets." This view of learning within science began to change, however, as inquiry learning evolved within the course. After the inquiry process was modeled in the classroom, the preservice teachers developed their own zoo inquiry investigation, took a field trip to the zoo, and then brought their collected data back to the classroom. This experience prompted this statement from Amy:

> I always saw a field trip as an opportunity to socialize with my friends, not a time to learn something. Now I can see how useful question development can be in learning. We had a great time working through how to find the answer to our inquiry question and didn't even think about how much we were learning.

Research Question 3: What benefits and/or obstacles do preservice teachers see in implementing the inquiry-based approach?

Though the preservice teachers were not in a field experience during the ten-week quarter, we discussed the benefits and/or obstacles there might be to implementing the inquiry-based approach in their future teaching. Their responses came from the post-questionnaires, journals, and focus group interviews.

As the preservice teachers wrote in their journals about the benefits and/or obstacles to using the inquiry-based approach, Mark described one benefit as "seeing social development of students through the use of inquiry. I think there would be positive interplay between mainstreamed children and others; they would help each other."

Julie felt that, "the students would retain more information through the use of the inquiry process. It seems if the students would be allowed to generate their own questions and have control over how to answer the questions, they would be more likely to remember what they did."

Also in the journals, several preservice teachers commented about how assessment would be more meaningful through the use of questioning, observation, checklists, and rubrics. About one-third of the preservice teachers felt that assessment would become more flexible through the use of journals, peer-group interactions, and projects.

There was general agreement that the benefits to using the inquiry-based approach far outweighed the negative factors. The preservice teachers in the focus group listed the following as benefits:

- Can include the local community in projects (reference to the zoo field trip)
- Gives students power
- Develops critical thinking
- Gets students more interested in science
- Allows students to generate their own questions
- Provides intrinsic motivation for students

Though obstacles to using inquiry in the classroom were a real concern to the preservice teachers, most felt that external factors (e.g., principals, testing

requirements, and curriculum limitations) would impede their use of inquiry-based education the most.

Stacy felt, "Schools will dictate when and how science will be taught. I don't think I will have a lot of control in this area. My experience is that I have to teach a specific way so that I can cover all of the material. Time will also be a factor."

Trying to target misconceptions that students had was a problem for all of the preservice teachers. The preservice teachers didn't feel comfortable with the students working with each other, as they felt it would be easier to develop misconceptions or have the students' misconceptions reinforced by others. They also felt that misconceptions might develop when the teacher wasn't working with the students on a continual basis. The preservice teachers were unable to get past misconceptions being reinforced in group settings to more positive aspects of grouping, such as communication and working together to solve a problem. Katie explained, "I don't know how comfortable I would be allowing the students to work together knowing that those who have misconceptions may be promoting these inaccuracies with others."

The preservice teachers in the focus group listed the following as obstacles:

- Not being able to cover all of the science material (time factor)
- Management issues, not being able to maintain control over students
- Concern that inquiry-based education would be over the heads of primary students (K-3)

The time factor was an issue for over 90% of the preservice teachers. They felt that they would be unable to cover all science curriculum requirements for their grade level if they used inquiry-based education. The depth vs. breadth issue is a concern for many teachers and may never entirely go away as a factor in teaching; however, the preservice teachers did seem to feel that the inquiry approach was important enough to use, even if it did take more time.

Losing control of the students was also a real concern of the preservice teachers, though about two-thirds (approximately 65%) felt that the students would be on-task and wouldn't pose a management problem. Stacy emphasized, "I doubt the students would be causing problems; they would be too interested in what they were doing. In fact, it might be easier to manage small groups of students."

As the preservice teachers had not seen primary students doing inquiry-based projects, it was difficult for them to feel that primary students would be developmentally ready for inquiry education. Scott stated, "I don't ever remember inquiry projects being a part of my elementary experiences, so it is hard for me to see how primary students would be ready for this type of work." Patricia had similar views: "It would be interesting to see a primary class in action with an inquiry project. I would be amazed that they could keep up."

Research Question 4: How do preservice teachers' ideas about how to teach science education change as a result of the implementation of the inquiry-based approach?

There were minimal responses on the pre-questionnaire about how to teach science and how the preservice teachers could relate inquiry-based education to their own teaching. For example, Andrea described inquiry learning as "asking questions and being curious about one's surroundings." This was a typical

response on the pre-questionnaire. After reviewing their assignments and the post-questionnaires, the responses became more detailed and focused on the experiences they had during the course. Describing inquiry learning on the post-questionnaire, Tracy explained, "Inquiry learning and the discovery approach are very similar. We can help students acquire knowledge through exploring the world around them. This involves focusing on the child and his or her interests. Their questions can become the questions we use during the inquiry process."

The engagement and exploration processes within inquiry learning impacted the preservice teachers' ideas about how to teach science. Over half of the preservice teachers at the beginning of the quarter had minimal understanding of Bloom's Taxonomy or the Five *E*s (engage, explore, explain, elaborate, evaluate) and how to use these concepts. As the quarter evolved, the preservice teachers began to go beyond thinking that inquiry learning was just a "hands-on" learning process to viewing it as more questioning and enhancement of a child's thinking. Teresa stated, "I can see how we have to move beyond playing with materials to actually questioning why things happen and attempting to follow a particular course of action through to the end to see what happens."

About three-quarters of the preservice teachers began to see themselves using a more centers-based structure when teaching science. They saw how students' learning styles could be accommodated when creating a center, for example, using computers with more visual learners and tape recorders with more oral learners.

The incorporation of inquiry-based teaching into other subject areas was discussed in the focus group interview as a way to ease the problem of time. Leslie explained, "I could see how using literature, the writing process, and math would easily fit into inquiry learning." Many of the preservice teachers felt they needed more information and guidance in integrating curriculum to be successful at this type of teaching approach.

Finally, over 90% of the preservice teachers expressed a desire to teach in an open environment in which the students generated questions and explored science together but felt overwhelmed with how to achieve a quality inquiry-based classroom. Sarah stated, "It would be wonderful if I could teach in a classroom where the students came up with things to study and we worked together to find information. I think the ideal class for me would be an inviting place in which the students were as excited about science as I am. I feel as though I will be on my own, and I don't know quite where to begin with this process."

Discussion

The preservice teachers' knowledge and understanding of how to implement inquiry learning deepened over the ten-week period. The preservice teachers seemed to gain some confidence in implementing inquiry learning. Though the preservice teachers tended to value children's involvement and promoting interest in science, they didn't seem to want to focus on developing meaningful, conceptual understanding. Inquiry projects are apparently not enough to ensure that preservice teachers feel confident or disposed to using inquiry in their own classrooms.

It is difficult to conclude that the ten-week methods course had a dramatic influence on the preservice teachers' attitudes and behaviors toward inquiry learning. The preservice teachers' reflective ideas and attitudes toward inquiry, however, seemed to gain strength within their journals and class discussion over the ten-week quarter. Fear of science content, little experience with the areas of

science, and not understanding concepts still are barriers to full acceptance of inquiry as well as even implementing science at all.

Preservice teachers need to have focused science teaching time with primary students to strengthen and support their confidence, attitude, and abilities to implement inquiry learning. It is imperative that the practicums in which preservice teachers experience primary classroom teaching have mentors who focus on implementing the inquiry process. These mentors need to be able to provide quality guidance, which means careful placement of preservice teachers within elementary schools.

The findings show that providing support and guidance for inquiry learning within a science methods course results in preservice teachers changing their conceptions about how science should be taught. Yet, a concern stems from the fact that the majority of the preservice teachers' had little prior experience with learning science through inquiry. It is crucial that exposure and guidance within inquiry learning begin at an early age. Promoting substantive content knowledge within authentic science learning experiences can be successfully included in both formal and informal education. Another final concern relates to the external factors influencing how preservice teachers perceive the way they can teach science. It is imperative that teacher educators participate in the decision-making process at local, state, and federal levels in regard to how PreK-3 curriculum is developed as well as show support for best teaching practices within science education.

Implications for Future Research

Further study is needed in what preservice teachers need to know and experience within their undergraduate programs to support and guide their implementation of inquiry-based science education when they are in their own classrooms.

- What influences beginning teachers to include inquiry-based teaching?
- Is involvement with inquiry within preservice teacher education enough to get beginning teachers to include it in their teaching? Direct observation of first-year teachers can document how much and what type of inquiry is being implemented in primary science classrooms.
- Would most of the obstacles (i.e., time, management, developmental issues, and group reinforcement of misconceptions) be alleviated or at least lessened somewhat if the preservice teachers were able to experience the inquiry approach being implemented in a primary classroom?

Conclusions

Included are recommendations that are framed by the results from this study. The following recommendations are focused on teacher education and highlight ideal learning situations for preservice teachers that support inquiry-based science education:

- Develop within both preservice teacher education courses and field experiences an environment that supports risk-taking and focuses on critical thinking.
- Allow preservice teachers multiple opportunities to practice implementing inquiry-based science projects that are mentored by cooperating teachers and supervisors who have experience with inquiry-based science education.

- Incorporate into science methods courses a time for practicing inquiry-based experiences that also includes reflection and discussion of the entire inquiry process.

Preservice teacher education is a time to study and consider what research has defined as the best teaching practices available. Inquiry-based science education allows students to see science as a subject that promotes exploration, investigation, question development, and evaluation of answers. Teaching using inquiry-based methods takes time and reflection but allows for an exciting way to explore the world.

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