

The Impact of a Field-Based, Inquiry-Focused Model of Instruction on Preservice Teachers' Science Learning and Attitudes

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Abstract

The purpose of this study was to determine the effects of a field-based, inquiry-focused geoscience course designed to provide preservice teachers with opportunities for active, hands-on scientific investigation and for gaining skills in inquiry pedagogy. Impact on student learning and attitudes was measured through (a) dependent t-tests comparing pre- and post-measures for students enrolled in the new field course ($n = 12$) and (b) analysis of covariance comparisons between field course students and education students in the traditional, classroom-based course ($n = 12$). Results showed that students in the field course scored significantly higher than students in the traditional course on measures of inquiry, confidence for teaching science courses, knowledge building, and cooperative learning. There was no significant difference between the two instructional groups on geoscience content knowledge, indicating that students in the two courses gained an equivalent amount of knowledge. Additionally, although there was no difference in students' use of low-level questions, the field class scored significantly higher in high-level questioning. Results provide evidence of the promise of this approach in helping preservice teachers develop the needed skills and content knowledge to create effective and engaging science courses for their students.

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Introduction

Many education majors in our nation's colleges and universities experience undergraduate science courses in a large introductory lecture and lab format. While these courses are rich in content, they often do not engage students in active, authentic scientific investigation, nor do they adequately address the problem-solving processes and inquiry skills required to teach science to others. It is difficult for our future teachers to create effective and engaging science courses for their students without exposure to

such experiences. The National Research Council Report on Teacher Education (2000a) recommends that university and college science, mathematics, and engineering departments should: (a) assume greater responsibility for offering courses that provide teachers with strong exposure to appropriate content and that model the kinds of pedagogical approaches appropriate for teaching that content, and (b) reexamine and redesign introductory courses to better accommodate the needs of practicing and future teachers. This paper discusses the impact of a new field-based, inquiry focused geoscience course designed to achieve these National Research Council recommendations.

The development of student inquiry skills and scientific literacy are emphasized in a variety of reports, standards and reform movements (American Association for the Advancement of Science, 1993; National Research Council, 1996, 2000b; U.S. Department of Labor, 2000). However, the research base on how to most effectively teach these skills remains limited (Anderson & Mitchener, 1994; Bybee & Fuchs, 2006; Smith & Wenk, 2006). Indeed, much of the research in science education has been conducted in physics and has focused on differences in how experts and novices approach and solve scientific problems (Bruning, Schraw, Norby, & Ronning, 2004). The lack of research is particularly acute within the discipline of geoscience, where a limited research base on effective pedagogy (Anderson & Mitchner, 1994) is compounded by the scarcity of research on how students develop an understanding of Earth sciences (Dodick & Orion, 2003).

One approach which offers promise to help preservice teachers develop the needed skills is direct field experience with opportunities for active, authentic scientific investigation and for gaining skills in inquiry pedagogy. Geoscience educators have maintained that field work is “critical to the development of spatial reasoning, to the ability to create integrated mental visualizations of Earth processes, and to developing facility with analyzing the quality and certainty of observational data supporting geoscience theories” (Manduca, Mogk, & Stillings, 2002, p. 21).

This research focused on investigating and documenting the effects of a new field-based, inquiry-focused geoscience college course. Specific objectives were to: (a) determine the effectiveness of a field-based, inquiry-focused course in impacting preservice teachers’ geoscience achievement, attitudes, and inquiry skills; and (b) assess the influence of field activities, as compared to classroom-contained activities, on preservice teachers’ geoscience achievement, attitudes, and inquiry skills.

Conceptual Framework

The past decade has been marked by fundamental changes in the way science should be taught, based on an emerging view of learning as an active process of sense making and mental construction (Bransford, Brown, & Cocking, 1999; Donovan, Bransford, & Pellegrino, 1999). Scientific expertise is not simply accumulating information but “a principled and coherent way of thinking and representing problems” (Shepard, 2000, pp. 6-7). Research on the development of scientific expertise confirms

the importance of helping students understand major scientific concepts and related factual information, and develop a variety of inquiry abilities (National Research Council, 2000b).

Scientific Inquiry

To enhance scientific literacy, educators are challenged to teach not only factual knowledge generated by science but also to teach the process of obtaining this information, scientific inquiry. Scientific inquiry is a complex human endeavor through which practitioners systematically investigate natural phenomena on Earth and in space. Scientific inquiry is not easy to define and perceptions can vary greatly depending on whom you ask. Much effort has gone into defining scientific inquiry in an attempt to provide a basis for science education purposes (e.g. National Research Council, 1996, American Association for the Advancement of Science, 1993).

Bybee (2002) describes the key elements of scientific inquiry as observation, hypothesis, inference, test, and feedback. However, scientific inquiry not only comprises these key practical components, it also requires recognition that scientific knowledge may change in response to new evidence (National Research Council, 2000). Furthermore, even though the basic process remains similar, scientists take many different paths in their quest to answer questions, and this search is fueled by curiosity, creativity and hard work. The creative process involved in developing hypotheses and theories to explain how the world works and then figuring out how they can be put to the test of reality is “as creative as writing poetry, composing music, or designing skyscrapers” (American Association for the Advancement of Science, 1990, n.p.).

The foundation for building students’ science literacy is outlined in the *National Science Education Standards* (National Research Council, 1996) and the companion book *Inquiry and the National Science Education Standards* (National Research Council, 2000b). These documents outline inquiry science as a three-legged stool (see also Vasquez, 2008, p. 12). The first leg of the stool is students’ ability to do science, i.e. the process of conducting an investigation. The second is students’ understanding of scientific inquiry or their knowledge of the nature of science. The third requires teachers to use inquiry as a set of teaching methods.

Too often science is taught as a collection of irrefutable, disconnected facts, with scientific investigations embodied in facts and principles offered by the textbook (National Science Foundation, 1997). This approach has many problems, not the least that it misses the opportunity to teach critical skills such as problem solving, communication, and critical thinking. Indeed, teaching science as strictly a body of information results in conveying only the abstractions and reduces the process of acquiring scientific knowledge into an artificially polished and overly simplified “how to” manual. As a consequence, this approach provides students with sanitized concepts that have few connections and little personal relevance. The result is rote memorization and limited comprehension of scientific information and almost complete ignorance of the process used to generate that information (Chiappetta & Koballa, 2002). In order to learn the process of scientific inquiry students need opportunities to ask questions, seek

answers, analyze data, discuss ideas, and apply scientific concepts in a variety of contexts to describe and explain phenomena (Ericsson, Krampe, & Tesche-Romer, 1993; National Research Council, 1996). The student must play an active role in formulating and testing hypotheses through data collection, rationalizing any conflicts in original beliefs and evidence, inventing a new conception that better explains the observed data, and communicating and sharing results.

Teaching teachers to successfully implement inquiry-based practices is a goal of teacher education and is a central component of the National Science Education Standards. While research has shown that teachers can develop the skills necessary for an inquiry-based classroom (Crawford, 2000; Wallace & Kang, 2004), preservice teachers face unique challenges in creating and successfully implementing inquiry lessons (Windschitl, 2002, 2004). To implement inquiry in the classroom, preservice teachers must be knowledgeable of, and comfortable using, the teaching techniques associated with inquiry-based education, including the processes of observation, question development, critical thinking, cooperative learning, general problem solving, and communicating and sharing results. Research has also documented the importance of preservice teachers' underlying beliefs and attitudes about teaching and science, which impact their teaching practices (Crawford, 1999; Pajares, 1992).

Field Experience

The experience of observing real geological structures in their natural environment and learning about the types of evidence that contribute to scientific understanding has been demonstrated to be of value in promoting inquiry and processing teaching behaviors. Results from learning research support the cognitive and affective value of incorporating a field experience into geoscience curricula. A comprehensive review of research studies dealing with the impact of fieldwork (Rickinson et al., 2004) concluded that well planned and delivered fieldwork provides experiences that cannot be duplicated in the classroom; it also positively impacts attitudes, leading to reinforcement between affective and cognitive domains of learning and higher level learning. Other research has shown that field experiences not only permit but actually encourage perception of the integrated whole, not just the individual parts (Kern & Carpenter, 1986).

The opportunity for direct hands-on experience provided by a field trip can be useful for transition from a concrete to abstract level of cognition as described by Piaget (1990). It can lead to conceptual change and refinement of student pre-conceptions (Tal, 2004). Furthermore, McKenzie, Utgard, and Lisowski (1986) showed that students who participated in a geological field trip for education majors exhibited significant gains in evaluation items that involved inquiry and investigative skills and that required active involvement. Field work has also been shown to be a key factor for improving students' understanding of geological time (Dodick & Orion, 2003).

The type of experience afforded by the field experience is a critical variable. Mackenzie and White (1982) compared the value of learning programs with *processing* field excursions versus learning programs plus *traditional* field excursions. The processing excursions emphasized students (a) becoming an active part of the experience

rather than mere observers, (b) generating information rather than receiving it, and (c) constructing their own records of the scene rather than accepting the teacher's version. Results documented the superior effectiveness of the processing excursions, particularly in fostering student retention.

“Authentic science,” a central strategy of science teaching, occurs through fieldwork. It requires that students assume active, investigative roles, thinking like a scientist and “doing” real science. Key to the success is not just providing students with a science immersion experience, but also helping them conceptualize science as a creative process and way of thinking rather than a defined body of content (National Research Council, 2007).

The need to integrate more authentic science experiences is prevalent in all K-12, undergraduate science, and teacher education courses. The traditional geology laboratory experience provided to undergraduates, although a valuable addition to the traditional lecture, can never be a substitute for evidence gathered directly from the field. It cannot replace the experience of observing real geological structures in their natural environment and learning about the types of evidence that contribute to scientific understanding, as well as extraneous evidence that can obscure (Manduca, Mogk, & Stillings, 2002). The goal of the new course described in this article was to teach geoscience concepts and inquiry methods by actively engaging students in fieldwork and invoking their use of complex reasoning and experimental inquiry skills.

Method

Instructional Treatments/Class Descriptions

This study involved a comparison between learning outcomes for students enrolled in the field-based inquiry-focused geoscience course and students in the on-campus, traditional classroom-based geoscience course. The field course was first offered at a large public Midwestern university during the 3-week summer session in 2004. The course provided students with the opportunity to study a variety of locations in Nebraska and Wyoming. It covered the traditional geology content offered in the classroom-based course, Geology 101, but also provided students with active, hands-on field-based opportunities to observe, compare, and investigate geological structures in their natural environment. Instructors focused on exposing students to the Earth systems concepts and content outlined in national science education standards. Class was conducted among a variety of rock exposures, on top of glacial deposits, in river valleys, and on mountainsides, literally bringing textbook concepts alive through real-life experiences in the field.

At the beginning of the course the instructors provided students with key questions to consider at each predetermined stop: (a) what makes the sediment and rocks there unique, (b) how were the rocks deposited or formed, and (c) what has occurred since their formation to lead to their current appearance. Students classified the world around them based on careful observation, comparison, and their growing geoscience understandings,

using field books, the instructors, and fellow students as resources. A mobile library, comprising a range of K-12 Earth science curricular materials and activities, was provided for students to utilize, examine, and critique. There was a clear focus on providing students with a solid background in geology, recognizing that a basic understanding of geologic principles was necessary before students could approach geology from an inquiry perspective.

The course provided an immersion in scientific inquiry, focusing on developing a new set of mental skills in the students. Students were provided many opportunities to utilize science process skills including observation, documentation, classification, questioning, formulation of hypotheses and models, and interpretation and debate. Opportunities were provided during the course to integrate the learning of geology with teaching practices. Instructors used the experiences in the field, the drive time in the vans, and the time spent at the daily campsites to introduce and discuss teaching curricula and strategies. Students were given sample boxes so that they could collect, label and classify samples of Earth materials to build a personal set of geoscience materials to use when they teach. Digital cameras were used to record images of natural phenomena. Each student received a DVD of the images to use in their future classroom activities. Near the end of the course students were asked to generate a series of lesson plans to teach plate tectonics.

A key strategy was modeling of the inquiry approach by the course instructors. At each of the stops along their route through Nebraska and Wyoming students were asked to come up with their own questions and try to answer the question with the resources provided. Students used their senses (i.e. how does a rock feel, taste, look) and other means to observe and gather information. They carefully explored each site, recorded their findings in their field books, and drew conclusions. Where possible, these conclusions were shared with the entire group, with the instructors facilitating the discussion through probing questions and offering alternative explanations or interpretations as appropriate. In keeping with the tradition of discussion and debate among scientists and scientific research teams, the two instructors sometimes engaged in a debate about possible interpretations.

As the trip progressed instructors encouraged students to compare and contrast concepts at the different sites and speculate underlying reasons for noted differences. A sample of topics and activities for day two of the trip is found in Table I.

Table I
Topics and Geoscience Principles Covered in Day 2 of Field Course

Location	Topics [Principles and Concepts]	Activity
Platte River	Sedimentology/Modern environments 1 – fluvial systems 1 [actualism]	Examine the Platte River System at a variety of locations along the route; measure stream velocity, collect sediment samples and examine grain size, shape, and composition; examine sedimentary structures
Lake McConaughy	Sedimentology/Modern environments 2 - lacustrine and eolian systems [actualism]	Collect sediment samples from sand dunes; compare and contrast with river sand
Medicine Bow	Soils 1	Dig soil pits in a variety of locations and record observations

A key component of the course was students' use of field books, which provided a log of their observations and explanations. These books became the students' documentation of the experience and were rich in illustrations of rock and soil deposits.

The traditional, classroom-based course was a general education lecture/lab course, Geology 101. Meeting three times per week for one hour each, it was also accompanied by a once-a-week 2.5 hour lab. This course focused primarily on classroom contained activities utilizing a structured approach. The lab allowed opportunities for students to interact with Earth materials, but within a classroom environment supplemented by limited, local field trips. A summary comparison of key differences between the field and traditional courses is presented in Table II.

Table II
Comparison of Field and Traditional Courses

Location	Traditional Classroom	Field
Learning goals	Geology concepts and principles	Geology concepts and principals Inquiry-focused pedagogy
Lab approach	Observing rock and sediment samples provided by teacher	Collecting own rock and sediment samples
Field trips	Local field trip	Total field immersion
Setting	Large lecture class with structured lab	Small group, learning community
Teaching approach	Instructor-centered	Student-centered; guided inquiry approach

The decision to use Geology 101 as a comparison group was made despite the fact that the goals of the two classes are not identical. The two courses shared a common purpose of increasing student knowledge of geoscience. The field class, however, had the additional goal of enhancing pedagogical understanding and increasing student understanding of the inquiry process. Thus, the classroom-based course served as a comparison group for measuring student geoscience knowledge and a control group for measuring the pedagogically-oriented outcomes of inquiry skills and attitudes and confidence for teaching science. Differences in contact hours for the two courses should also be noted. The on-campus course carried 4 hours of credit; the field course carried 3. However, the nature of the field class meant that students had virtually unlimited access to instructors with opportunities for interaction beyond the typical instructional time period. The amount of instructor-student contact depended on student initiative; some students took advantage of the opportunity and others did not.

Participants and Data Collection

Since students in the field-based course were all education majors, only education majors enrolled in the traditional classroom-based course for Physical Geology were invited to participate in this research project. Research participants included the 12 students enrolled in the field-based course (Summer Session, 2004 and 2005) and 12 education students enrolled in the classroom-based course (Fall 2004 and Spring 2005). The small numbers were due to the limited subject pool; however, we were able to achieve a balanced design of 12 subjects per condition, which is important in meeting the ANCOVA assumption of equality of variances. Based on previous studies showing significant effects for various attitudinal and cognitive measures for students participating in field experiences, our sample size was deemed sensitive enough to achieve the desired effects. In particular, Kern and Carpenter (1984) found highly significant effects ($p < .10$, Cohen's d [effect size] = 1.24 to 1.60 [Cohen, 1988]) for the impact of a field experience

on undergraduate students ratings of value, interest and attitude towards geoscience and geoscience course topics. McKenzie et al. (1986) also showed significant gains ($p < .05$) for inquiry and investigative skills for preservice teachers involved in a field course.

There was no deliberate matching of students in the two groups; however, the two groups were surprisingly similar on several key demographics, including gender, classification, number of previous science courses taken, and major. Table III provides a breakdown of student characteristics.

Table III
Comparison of student demographics in field and traditional class

	Field	Classroom
Gender		
Males	2	2
Females	10	10
Classification		
Freshman	1	1
Sophomore	4	4
Junior	4	4
Senior	3	3
Previous Science Courses	Mean = 1	Mean = 1
Major		
Elem. Ed.	5	5
Middle School	1	1
Secondary Ed.	0	5
Special Ed.	1	0
Science	3	0
Music	1	0
English	1	0
General Studies	0	1

All participating students completed a packet of questionnaires at the beginning of the course and again at the end of the course.

Measures

A variety of instruments were used to assess the impact of a field-based geoscience course on preservice teachers' cognitive and attitudinal perceptions, behaviors, and skills. With one exception (the multiple choice content test), all instruments were previously published and validated. Internal reliability estimates (Cronbach Alpha) for each of the instruments and/or scales, calculated from our research data, ranged from .78 to .98. Following is a description of the measures and their instrumentation.

Inquiry skills and attitudes. Key elements of inquiry are careful observation, the development of questioning skills, the use of cooperative learning, and the differentiation between scientific observation and inference. Two instruments were used to measure these elements: (a) *Student Perceptions of Classroom Knowledge-Building (SPOCK)* (Resta et al., n.d.) and (b) an observation/inference instrument using a picture prompt format recommended by Molitar and George (1976). *SPOCK* has several scales to measure students' knowledge building and classroom perceptions. Students are asked to indicate how frequently they think the activities described in the items occurred in previous (pre) and the current (post) science class. Items are on a 5-point-Likert format (1 = almost never, occurred on a very rare occasion or not at all; to 5 = almost always, usually or always occurred). The two *SPOCK* scales used to measure questioning skills were (a) question asking - low level and (b) question asking - high level. Low-level questions focused on learning the answers for the test and what the instructor wanted students to learn. High-level questions examined students' use of high-level questions to more fully understand the content, satisfy their curiosity, and help them learn the material.

Cooperative learning was measured through a *SPOCK* scale focusing on the degree to which students worked cooperatively on assignments and actively shared ideas. A sample question was "My classmates and I worked together to help each other understand the material."

A final inquiry skill assessed was the differentiation between scientific observation and inference. This outcome variable was included in the research design because of the importance of this skill within the geoscience field. Evidence in the geosciences is largely observational, and a significant portion of geoscientists' work involves observing natural phenomena and inferring events in the past or processes beyond human perception (Manduca, Mogk, & Stillings, 2002). This skill was measured by an observation/inferences instrument consisting of 6 picture items depicting an easily recognized event, i.e. a broken window with a baseball lying on the floor. Students were asked to make both observations and inferences about the event. A total average score for the scale was derived with 100 total possible points.

Knowledge. Two knowledge measures were used in this research. Geoscience content knowledge was measured by a 30-item multiple-choice assessment prepared by the course instructors based on questions that had been developed for the traditional, on-campus class.

Another knowledge measure, focusing on deep learning, was drawn from the knowledge building subscale from *SPOCK*. This scale examined the extent to which students related new class knowledge to prior knowledge, went beyond the class material and developed new understandings and deeper learning.

Confidence for teaching science. Students' confidence for teaching science-related courses was measured through a 15-item scale that asked students to think about themselves as future teachers and rate how confident they were in achieving various

classroom tasks (i.e., teach concepts that students are expected to understand, write lesson plans that interest students, etc.). Ratings range between 0 (no chance in achieving the tasks) and 100 (completely certain that they could achieve the tasks). A total average score for the scale was calculated. This scale was derived from Bandura's (1977) theory of self-efficacy which is based on one's belief in their ability to cope with a task. Research has shown that teacher efficacy is related to positive teaching behavior and student outcomes (Enochs, Scharmann, & Riggs, 1995; Woolfolk & Hoy, 1990).

Data Analysis

Two sets of statistical analyses were conducted. The first was a dependent t-test between pre- and post-measures for students in the field class. This test was intended to determine any significant increases or decreases in the cognitive and attitudinal measures as a result of taking the field course. The primary analysis was a one-way analysis of covariance (ANCOVA) examining differences in post-measures between the field and traditional classes. The ANCOVA used the pre-measures as covariates to adjust for initial differences between the two class groups. Despite the small sample size, all significant ANCOVA analyses met the homogeneity-of-slopes assumption. There were no significant interactions between the covariate and group (field, traditional class); group differences on the dependent variable among groups did not vary as a function of the covariate.

Results

Results are summarized in Table IV, which shows the average score per measure, the t- and F- statistics, effect sizes, and the level of significance. It is important to note that, despite the small number of subjects, all of the hypothesized effects were significant and the effects sizes for the significant results were all large (Cohen's $d > .8$ and $\eta^2 > .14$ [Cohen, 1988]).

Table IV
Summary of t-test and ANCOVA analyses

Measure	Field-Class			Cohen's D Effect Size	Sig.	Regular Class Post Mean	F	Eta ² Effect Size	Sig.	
	Means (n=12)		t - statistic							
	Pre	Post								
Inquiry Skills and Attitudes										
Question Asking Low Level (SPOCK subscale with 20 possible points)	.86	14.08	12.42	1.04	.30	.32	10.92	.14	.01	.71
Question Asking High Level (SPOCK subscale with 25 possible points)	.96	19.5	22.0	2.09	.60	.06	12.92	13.43	.39	.001***
Cooperative Learning (SPOCK subscale with 25 possible points)	.91	16.08	22.33	3.95	1.14	.002**	18.58	4.69	.18	.04*
Observations and Inferences Knowledge	.78	57%	77%	5.07	1.46	.000***	64%	10.99	.36	.003**
Content Knowledge	.81	38%	51%	3.99	1.15	.002**	49%	.15	.01	.70
Knowledge Building (SPOCK subscale with 50 possible points)	.91	33.0	40.17	3.08	.89	.01**	29.58	17.6	.46	.000***
Confidence Teaching Science Related Courses (100 point scale)	.98	58.48	80.13	3.73	1.08	.003**	78.51	6.0	.22	.02*

* $p < .05$, ** $p < .01$, *** $p < .001$

Results show that the field course significantly increased student use of cooperative learning strategies, differentiation between observations and inferences, deep learning (knowledge building), and confidence in teaching science. The field course was also superior to the traditional, classroom-based course in fostering student use of high-level questions, cooperative learning, differentiation between observation and inferences, deep learning, and confidence in teaching science.

Discussion

Inquiry Skills and Attitudes

A particularly enlightening result was that the field course promoted students' high-level questioning, but had no impact on low-level questioning. Students were more likely to increase their use of high-level questions that allowed them to more fully understand the content, satisfy their curiosity, and help them learn the material. They did not increase low-level questions that focused on learning the answers for a test. Results show that students in the field class were intent on gaining understanding. It is interesting that the high-level questioning scores for the field class increased from pre to post, while the scores for the traditional classroom actually decreased. The field work and the instructor modeling of the scientific inquiry process contributed to student development of higher-order questioning skills, while traditional classroom settings and strategies had no positive impact.

Both the t-test and ANCOVA were significant for the cooperative learning measure, indicating that the field experience increased students' use of cooperative learning strategies. Again, the modeling of instructional strategies to enhance cooperative learning and sharing of ideas and explanations was important to the field course success and provided students with a model of how cooperative learning strategies could be implemented in a K-12 classroom.

The t-test and ANCOVA for the observation and inference measure were both significant, indicating that the field experience directly contributed to student differentiation of observation and inferences, which is a critical inquiry skill for prospective K-12 science teachers. It is especially encouraging that the field students scored higher on the observation portion of the assessment since careful observation is a critical skill in geoscience.

Adjusting to an inquiry-based teaching approach was not always easy for students. Comments from students and reflections in their field books documented students' initial frustration with the student-centered approach, and particularly the instructors' penchant for encouraging students to answer their own questions and not rely on the instructor for quick answers. As one student reflected in his field book mid-way through the course, "When a students' main (all) experiences are lecture-based, it can be difficult for a student to shift gears into inquiry. I suspect myself and my classmates are experiencing difficulty shifting gears." By the end of the course students felt more comfortable with the inquiry approach and developed a sense of self-confidence in their

own abilities to carry out an investigation, develop a hypothesis, and share results with fellow students and instructors to refine conclusions.

Knowledge Measures

T-test results for the content knowledge multiple choice assessment and the *SPOCK* knowledge building scale were both significant, indicating that the field experience significantly increased students' knowledge in both these areas. In addition, the ANCOVA was significant for the knowledge building (deep learning) measure, but not the content knowledge measure. These results confirm that field course students gained an equivalent amount of content knowledge as students in the traditional class but increased in their perceptions of their abilities to expand, extend, and transfer their knowledge. Findings are consistent with hypothesis that the field pedagogy would promote deeper, contextual learning through the opportunity to experience "real" Earth science through fieldwork. These results support previous research (Kern & Carpenter, 1986) documenting the effectiveness of field experience in allowing students to develop a holistic view of geoscience content.

Confidence in Teaching Science

The t-test and ANCOVA statistical tests for this measure were both significant, indicating that the field experience positively impacted preservice teachers' confidence in teaching science. This is consistent with our hypothesis that the field experience, which modeled effective science pedagogy and provided basic geoscience content knowledge, would result in increased student confidence in their ability to teach science.

Summary

The field-based, inquiry-focused course model developed for delivery of an undergraduate geology course significantly impacted key skills and attitudes of preservice teachers. This research demonstrated that students participating in the field class scored significantly higher than their counterparts in the traditional classroom-based course on inquiry skills and attitudes, deep learning, and confidence for teaching science-related courses. It is important to note that the field class scored equally well on the multiple choice content test as students in the traditional course. They gained an equivalent amount of geoscience knowledge while concurrently gaining confidence in their science teaching abilities and increasing their perceived use of high-level questions and cooperative learning strategies. These results provide evidence that this instructional model can be effective in promoting attitudes, knowledge and skills necessary for teaching K-12 science. Future research will refine the course model by incorporating a pedagogical component, providing preservice teachers an opportunity to use their field experiences as the basis for developing and teaching a sample geoscience unit to middle school students. We believe this strategy will help students make the transition from practicing inquiry as a student to implementing inquiry as a teacher. Observational measures to evaluate preservice teachers' pedagogical skills in actual teaching situations will also be added to reinforce the self-report data reported in this study.

While these results provide evidence of the promise and success of this approach, the long-term impacts are equally important. How effective are the field students in implementing inquiry strategies in their classroom? The research team is maintaining contact with students who have completed the course and taken teaching positions, with the hope of documenting their implementation of inquiry-based approaches in their own classroom. Ultimately, the long-term goal of this research is to develop an optimal model by which preservice educators are provided with the necessary content knowledge and pedagogical skills to feel empowered, capable, and prepared to create effective and engaging science courses for their students.

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