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An Immersive Geoscience Field Course as a Vehicle for Exploring the Nature of Science

Nathan Anderson Quarderer [1*], Ted Neal [2], John Dunkhase [2]

[1] *Northeast Iowa Community College, Calmar, Iowa, USA*
[2] *University of Iowa, Iowa City, Iowa, USA*

* CORRESPONDENCE: ✉ quarderern@nicc.edu

ABSTRACT

Preservice science teachers need to be put into situations where their existing conceptions of science, teaching, and learning are challenged in immersive, inquiry-based learning environments, before being asked to create similar spaces in their own classrooms. One approach to meeting this objective is through field-based geoscience courses designed for preservice teachers and education majors. The benefits that these experiences provide for preservice teachers' self-efficacy, understanding of the nature of science, and science content knowledge are well documented. The study reported on here describes one such geoscience field course tailored for preservice elementary and secondary science instructors, and the impact that experience had on participating students' ideas about science and teaching. Qualitative methods including In Vivo and emotion coding of transcripts from informal interviews with participants offer a unique opportunity for these preservice teachers' voices to be heard, in their own words, as they reflect on their week spent in the field, and how that experience informed their conceptions of the nature of science. Findings suggest that the field geology course challenged preservice teachers' existing epistemologies of science as they demonstrated a new understanding of the empirical, creative, and tentative aspects of scientific knowledge. Discussion of how these findings might be incorporated into the broader collection of science teacher preparation efforts is included.

Keywords: geoscience, immersive, field-based, nature of science

INTRODUCTION

Reform efforts in the field of science education have long pushed for the development of classrooms where the processes and practices of science and inquiry are valued over the coverage of content (National Research Council, 1996; NGSS Lead States, 2013). If today's pool of preservice science teachers are expected to go on to create immersive, student-centered learning environments in their own classrooms, they need to be put into similar situations as part of their teacher education programs. Science educators need to be provided with ample opportunity to construct their epistemic orientations towards teaching (Suh & Park, 2016), develop their understanding of the nature of science (Lederman et al., 1998), and see for themselves how these ideas can be carried forward into their own classrooms (McLaughlin & MacFadden, 2014).

All too often, preservice teachers arrive to their science teaching methods courses with limited conceptions about the nature of science, having themselves come from traditional learning environments where a premium was placed on covering content, with little emphasis on inquiry (Abd-El Khalick & Lederman, 2000; Gallagher, 1991; King, 1991). The identity that preservice teachers hold about what it means to be a scientist in general, and a science teacher in particular, can be superficial and littered with stereotypes about how scientific

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knowledge gets constructed, influencing their approach to teaching and learning once they enter their classrooms (Mensah, 2011; Thomas & Pedersen, 2003). The curriculum at the heart of science teacher preparation programs must include practical applications offering preservice teachers exposure to the practices being promoted in their teaching methods coursework.

To help address these needs, an immersive weeklong field geology course was created to provide preservice science teachers with an opportunity to experience directly the inquiry-based approaches they've discussed in their science teaching methods classes. Students enrolled in the geoscience course spend a week immersed in the field exploring various geological formations throughout the Elk Mountains of Colorado's Western Rockies. While in the field, students are led by two experienced science education faculty members as they collect samples to create their own rock boxes, while piecing together a story to help better understand how these rock formations came to be. Participating students are assessed in small groups at the end of the week via interviews with the lead instructors. The qualitative study described here focuses on a small group of students enrolled in the course during the summer of 2018, using these participants' own words to report on how the experience challenged their ideas about science teaching. This research is informed by the nature of science (NOS) literature and prior studies focused on the impact that inquiry-based geoscience courses have on prospective and in-service science teachers' geoscience content knowledge, and NOS conceptions. The direction of this work was guided by a central research question: What impact does an immersive field geology course have on preservice teachers' conceptions of the nature of science, learning, and teaching?

THEORETICAL BACKGROUND

Nature of Science

Along with helping students gain a deeper understanding of fundamental geologic materials and processes, a desired learning outcome of the course described here was that participants develop a deeper understanding of the tentative, empirical, creative, and human aspects of NOS. Despite the lack of a common definition of NOS, researchers tend to believe that NOS is concerned with the epistemological assumptions framing the processes of science including collecting and interpreting data and drawing conclusions from those results (Lederman, 1992; Lederman et al., 2002). There has been extensive research into the views about NOS held by adolescents (Carey et al., 1989; Driver et al., 1996; Khishfe, 2008), and undergraduates (Ryder et al., 1999). Findings typically suggest that students, regardless of age, tend to possess naïve, knowledge unproblematic conceptions of NOS consistent with a traditional objectivist epistemology of science. According to these studies, students generally see scientific knowledge as certain, disconnected from creative, human influences, where the work of scientists includes seeking out the "truth" through their use of a prescriptive scientific method.

Characterization of science teachers' NOS conceptions has long been a topic of interest within the science education research community. Working with veteran K-12 science teachers, Gallagher (1991) reported on participants' unsettling views of NOS, treating science as a body of knowledge to be covered during much of their time spent teaching. Gallagher credits this lack of emphasis on NOS to the poor preparation they received in previous science courses where, the focus has traditionally been on the coverage of content, with little to no attention paid to the origins of scientific ideas. King (1991) reported similar findings in a study involving a small group of teachers at Stanford. Participants in this study reported having limited background in the history and philosophy of science and seemed unsure about how to incorporate aspects of NOS into their teaching.

In an extensive review of the literature on students' and teachers' conceptions of NOS, Lederman (1992) demonstrated that teachers' conceptions of NOS are seen as inadequate, and that placing direct emphasis on NOS in teacher preparation programs have been shown to improve teachers' understanding of NOS. In a subsequent review, Abd El-Khalick and Lederman (2000) revealed that interventions featuring an explicit approach to teaching certain aspects of NOS were more effective at bringing about changes in teachers' conceptions of NOS than were similar interventions where NOS was only addressed implicitly through engagement with inquiry-based activities. The authors suggest that without purposeful attention to NOS in teacher preparation programs, preservice teachers are unlikely to move beyond their limited conceptions of NOS developed over years of previous coursework.

As it relates to the NOS conceptions held by preservice teachers, early work by Carey and Strauss (1968) asked participants to provide a written essay explaining their ideas about NOS. Findings showed that prospective teachers lack the background in the philosophy of science needed to effectively teach NOS, lack ample opportunity to develop a sufficient understanding of NOS, and would benefit from teaching methods courses that explicitly emphasize NOS. In a series of three studies (Abd-El-Khalick et al., 1998; Bell et al., 2000; Lederman et al., 2001) researchers attempted to delineate the factors that contribute to preservice teachers' ability to translate NOS conceptions into teaching practices in the classroom as part of their student teaching requirements. Their findings demonstrated that asking preservice secondary science teachers to learn about NOS in their methods courses while simultaneously attempting to teach NOS as part of their student teaching requirements resulted in poor alignment between reported NOS conceptions and instructional practices (Abd-El-Khalick et al., 1998). When instruction on NOS and student teaching about NOS were separated temporally (Bell et al., 2000), preservice teachers were better able to explicitly plan for and teach NOS in the classroom. Ultimately, the authors were able to show that until preservice teachers demonstrate that they have internalized the importance of including NOS in their teaching, their understanding and teaching practices will struggle to align (Lederman et al., 2001).

Recent work focused on preservice teachers in Turkey who participated in an intervention focused on the use visual heuristics to help better represent their conceptions of NOS aspects including scientific knowledge, along with science practices (Erduran & Kaya, 2018). Findings from participants' visual representations, along with pre- and post-intervention interviews suggest that asking preservice teachers to represent their ideas about NOS visually through drawings can contribute to the shaping of their epistemic insights. Other contemporary research has examined the NOS conceptions held by preservice teachers in a range of contexts that include the tentative nature of scientific models and theories (Reinisch & Krüger, 2018), inquiry-based science lab environments (Martin-Dunlop, 2013; Ozgelen et al., 2013), and the history of the atom (Ward & Haigh, 2017). While the findings from these more recent studies have been mixed, they point to the potential that an explicit-reflective approach can have in shaping prospective teachers' conceptions of NOS.

Inquiry-Based Geoscience Courses

Numerous studies have investigated the impact that inquiry-focused field-based geoscience courses have on science teachers' geology content knowledge, and conceptions about science learning. Much of this research has been based on the premise that existing teacher preparation and professional development opportunities rely too heavily on traditional, teacher-centered, lecture/lab approaches of instruction, with little emphasis on NOS and inquiry-based pedagogical techniques. Nugent et al. (2012) looked at the impact that an immersive, field-based geoscience course had on preservice teachers' geology content knowledge and attitudes towards science. When compared with a control group, participants in the field course gained an equivalent amount of content knowledge, but reported significantly higher scores on measures designed to assess deep learning and attitudes about inquiry-based science teaching. The field course also contributed positively to students' use of high-level questioning and conceptions of NOS including their ability to differentiate between observation and inference. They argue preservice science teachers should be given the opportunity to experience inquiry-based pedagogy as students, and their findings provide evidence of the benefits that such an approach offers in helping students transition from learning about inquiry as undergraduates, to implementing those practices in their K-12 classrooms.

In their work with in-service science teachers, Hemler and Repine (2006) observed a small group of K-12 educators as they participated in an eight-month study focusing on how an immersive, inquiry-based field experience impacted participants' understanding of NOS. Qualitative data from participants' journals and group interviews reveled that this authentic, field-based experience gave teachers a new appreciation for the work that scientists do, as they attempt to paint a picture of the events that contribute to a geologic formation, without ever having all of the necessary information required to re-create the 'true' story.

Almquist et al. (2011) looked at the long-term impact that a geoscience professional development (PD) program had on participating K-12 teachers' ability to understand and ultimately implement paleontological, and geospatial topics in their classrooms. A unique feature of the PD experience included an opportunity for middle-school students to participate in the field study alongside the teachers, providing participants with the chance to turn around and teach their newly acquired geoscience content knowledge while in the field. Instructors of the course refrained from 'show & tell' and, rather, gave participants an opportunity to explore and observe field sites on their own, coming up with claims and arguments about the history of a location from relevant evidence. Follow-up interviews occurring one and two years after the PD indicate that participating teachers found the experience to be positive, and report using many of the activities and lessons they took away from the PD in their own classrooms. In a study that investigated an immersive PD experience for high-school science teachers, McLaughlin and MacFadden (2014) tracked participants prior to and following a field study that took place in the Panama Canal. Participants worked alongside a multidisciplinary team scientists of for two weeks in the field giving them firsthand experience in the practices of science including fossil sampling and developing claims from evidence. Based on interviews and follow-up classroom observations, these teachers' conceptions of the tentative, empirical, and cultural aspects of NOS were more informed as a result of the authentic field experience, translating into meaningful learning experiences with their own students.

Taken together, findings from the literature on NOS and inquiry-based geoscience courses designed for prospective and in-service teachers suggests a discrepancy between the conceptions of NOS held by students and classroom science teachers, and those prescribed by science education researchers. Inquiry-based geoscience courses have been shown to positively impact teachers' geoscience content knowledge, sense of self-efficacy, and understanding of NOS including how scientific knowledge is constructed. The research described in this study has potential to contribute to the existing literature on preservice teacher preparation, with an aim of fostering the development of informed conceptions of NOS through immersive geoscience fieldwork.

Course Description

The geoscience course described here originated in the early 1990's as an applied Earth and environmental science course for in-service teachers seeking graduate credit through a public university in the Midwestern United States. While preparing for the geoscience unit one summer, the lead instructor half-jokingly remarked to the students that he could either present them with a slide show of photos that he had taken in the field, or they could go visit those same sites, giving students the chance to personally experience the geology for themselves. Calling his bluff, the students took him up on the offer, and before they knew it the class was exploring and sampling the geology of the West Elk Mountains near Gunnison, and Crested Butte, Colorado.

Over time the course has evolved from a more strenuous, two-week experience for in-service teachers that included back-packing, orienteering, and camping in the field, to the current nine-day iteration (includes travel time) tailored to preservice teachers featuring numerous opportunities for roadside geology. This allows for multiple site visits throughout the week including a description and history of each field site, followed by sample collection and identification. As the week goes on, the lessons conducted at each stop in the field become more student-centered, largely driven by their own observations and follow-up questions. Students spend time in the evenings studying in small groups at their condos, reviewing what took place during the day, and the rocks they had collected while in the field. The week concludes with students participating in small-group exit interviews with the lead instructors to assess their geoscience content knowledge. It is not an aim of the lead instructors that the students enrolled in the course become experts in geology, but, rather, that they gain experience with a storytelling approach to science teaching, while developing relevant field geology content knowledge and more informed NOS conceptions.

Prior to heading into the field, students engage in an activity known as 'Book Bits' (Yopp & Yopp, 2003), intended to jump-start their thinking processes about the nature of science knowledge, demonstrating how evidence gets pieced together to tell a story. To begin the 'Book Bits' activity, groups of students are given envelopes containing random pages of a book that have been cut into small pieces. Based on the bits of text on the individual pieces of paper, students are asked to come up with their best interpretation of what they think that story is about. Students are asked to name any characters, identify relationships between individuals in the story, and determine what those characters are doing. As more evidence becomes available, groups of students challenge the claims made by their classmates about the details of the story. Much like practicing geologists in the field trying to piece together evidence through sampling and observation without having access to the complete geologic record, students engaging in the 'Book Bits' activity must do their best to identify the themes and big ideas of the story, without ever having the whole book in front of them. Previous work focusing on the role of storytelling as a tool in science teaching demonstrated positive impacts with elementary education majors gaining more sophisticated views of NOS following intervention (Bickmore et al., 2009). In line with these findings, it is our view that science, and geology in particular, is all about storytelling, and the 'Book Bits' activity coupled with an immersive field experience can be an effective means of helping preservice teachers gain comfort with the use of storytelling in their science teaching practice, while developing more informed NOS conceptions.

Field Sampling

The week in the field officially begins prior to students arriving in Crested Butte. Traveling westward, students first stop near Morrison, Colorado, just outside Denver to observe dinosaur footprints left behind in the Dakota sandstone that once made up the sand bars and beaches along the western edge of the inland Cretaceous sea, in addition to the nonconformity at Red Rocks spanning a gap of over 1.4 billion years in the geologic record. Here students begin to wonder about what might have happened to the material that once filled this gap in geologic time. Upon arrival to their destination in the Elk Mountains of Western Colorado, the day begins with a short hike along the southwestern slope of Mt. Crested Butte. Looking south, Whetstone Mountain looms to the west as students observe moraines, cirques, kettle lakes, and U-shaped valleys that are indicative of the glacial activity that helped shape the Rockies 10,000 years ago during the most recent ice age. After lunch, students drive to the top of Anthracite Mesa in the Gunnison National Forest to an elevation of nearly 11,000', providing them with an unforgettable view down the glacially carved valley to the town of Mt. Crested Butte below. Here the students are asked to think about what this area would have looked like 135 million years ago when the Cretaceous Sea covered much of North America. Heading back downhill, students stop along the banks of the Slate River where they are introduced to the rolling hills of Mancos shale, leftover sedimentary material from the inland Cretaceous sea, including deposits of slate that had at one point been injected with a hydrothermal solution leaving behind intrusions filled with aplite, quartz, and iron pyrite. Near the end of the first day in the field students visit sites further down the mountain to collect samples of anthracite coal and Mesa Verde sandstone, remnants of the swamp and beach, respectively, of the inland sea that began to regress during the Paleocene.

Traveling southwest out of Gunnison, the 2nd day in the field begins at Hartman Rocks, the site of a Precambrian granite batholith, evidence of the tectonic activity that helped shape much of the igneous material of early Western Colorado. From there, students continue westward to collect Cenozoic samples of welded ash fall tuff and West Elk breccia, shedding light on Colorado's volcanic past, at Curecanti Recreation area along the Gunnison River. In between, a stop on the shore of the Blue Mesa Reservoir allowed for collection of samples from the Morrison formation. As the day went on, students traveled further back in time as specimens of Precambrian gneiss, and schist were collected below the Blue Mesa and Morrow Point dams. After lunch, Cretaceous Mancos shale was observed sitting *below* gneiss at another unconformity along the Cimarron fault line. The 2nd day in the field ends with one more incredible view and a visit to the Dragon Point lookout in the Black Canyon of the Gunnison National Park. Here students observed yet another unconformity with 200 million-year-old Entrada sandstone sitting atop the Precambrian gneiss and pegmatite that adorn Painted Wall. Again, students are asked to think about what might have caused this gap in the geologic record.

The 3rd day of field sampling begins just south of the town of Almont where students are once again faced with another unconformity. Here, samples from the Morrison formation and Entrada sandstone are seen sitting atop biotite and muscovite schist, representing a gap of over one billion years in the geologic record, leaving students to pose the question: where is all the missing material? From there, students drive back north towards Cement Creek just east of Crested Butte. Rolling hills consisting of Mancos shale and outcroppings of Mississippian Leadville limestone are observed and sampled as students travel uphill along the banks of the creek, marking the first Paleozoic material that students have encountered so far after three days in the field. Could these be the first signs of the missing material? Further up Cement Creek students stop for lunch at a site littered with conglomerate rocks containing rounded bits of granite, limestone, and quartzite thought to be erosional remnants of the Ancestral Rockies, and members of the Pennsylvanian and Permian Maroon formation. The rounded bits and pieces of Precambrian granite and Cambrian Sawatch quartzite that make up the conglomerate are the same materials that students sampled earlier in the week cemented together with Paleozoic limestone. It is here that the lightbulb goes off for many of the students as they begin to realize that the material they're sampling and standing on are the missing pieces in the geologic record that they were looking for just down the road at Almont. Each of the unconformities that students observed marks a gap of over a billion years in geologic time and here at Cement Creek they begin to see where some of those missing deposits may have ended up. The question now becomes how did it end up here and where is the rest of it?

Piecing it together

The samples and observations as they are presented during these first three days spent in the field are not unlike the torn bits and pieces of book pages that students tried putting together in the 'Book Bits' activity near the start of their field experience. Students collected samples from different eras and epochs that help tell the story of Western Colorado's geologic history. It was now up to the students to put these pieces back together in a way that made sense to them, and in an order that was consistent with the evidence and their field notes. Using a copy of the geologic time scale and their field samples now organized into rock boxes, students attempted to map what they had observed and collected in the field chronologically through geologic time to tell the story of Western Colorado going back nearly 1.7 billion years.

Beginning with the Precambrian gneisses and schists seen near Almont and the Black Canyon of the Gunnison, students concluded that these parent materials, the result of metamorphic processes occurring deep below Earth's surface, were exposed over time through uplifting and weathering events (Hansen, 1965). Students repeatedly observed unconformities where these basement rocks were covered with much younger Mesozoic sandstones, leading students to wonder where all the missing material may have gone? This question was finally answered on the 3rd day in the field when students discovered the Paleozoic Leadville limestone, and Maroon formation near Cement Creek. Based on the heavily rounded nature of the contents of the conglomerate sampled at Cement Creek, students concluded that this material, largely missing from the area, was likely swept away in a series of flooding events that occurred as riverine systems aided in the weathering of the Ancestral Rockies 200-250 million years ago.

During the Mesozoic era the climate in this part of North America oscillated between wet/humid and hot/arid leading to periods of desert-like conditions in the Early and Middle Jurassic, while the inland sea repeatedly transgressed and regressed during the Late Jurassic and into the Cretaceous. All the activity in the Mesozoic era is recorded in the Entrada, Dakota, and Mesa Verde sandstones, Mancos shale, anthracite coal specimens, along with samples of the Morrison formation (Day & Bove, 2004). Mountain building began again in the early Cenozoic when the inland sea finally regressed, giving way to a period of volcanic activity in what is now the West Elk and San Juan Mountains. Students saw evidence of this in the samples of West Elk breccia, welded ash fall tuff, and Hoodoos near the Curecanti Recreation Area. Finally, students saw evidence of the glacial activity that took place just within the last 20,000 years, responsible for many of the alpine features they observed on their first day in the field. Each of these observations and sampling sites have been mapped onto a geologic time scale with pieces of the storyline included for context (**Figure 1**). Together, they help tell the story of how Western Colorado's geology has changed and shaped the land going back 1.7 billion years.

Assessment

The literature suggests that an immersive, inquiry-based approach to geoscience education for pre- and in-service science teachers can lead to improved NOS conceptions, attitudes about inquiry-based learning, and growth in geoscience content knowledge. Many of these studies rely on quantitative measures including geoscience concept inventories, questionnaires, and Likert-type survey instruments. What makes the field course described in this study unique from others is the approach to assessment adopted by the lead instructors to measure student learning following completion of the course. At the end of the week in the field, students gather in small groups for exit interviews with the lead instructors. Participants are asked a series of questions and can choose a level of difficulty based on their confidence. For example, participants seeking secondary earth science teaching endorsements tended to ask for more challenging exit interview questions than those students pursing elementary teaching licensures. This format allows the lead instructors to tailor their questions to the students' background, and the grade level these preservice teachers intend to be working with once in the classroom. Questions ranged from recall of facts including basic descriptions of samples, to more open-ended items that ask students to discuss the relationships between two or more samples. Students are also asked to clarify how certain samples fit together to help tell the story of Western Colorado's geologic history.

A secondary form of assessment that was introduced during summer 2018 iteration of the field course included informal interviews between participating students and a graduate research assistant. While the studies reviewed in the literature offer useful insights into the benefits that hands-on, field geology courses provide for practicing and preservice science educators, pre- and post-test scores can only say so much about the impact that these inquiry-based field experiences have on participants' views of the nature of science (Lederman et al., 1998), and their ideas about learning and teaching. There appears to be a gap in the research when it comes to opportunities for preservice teachers' voices to be heard, through their own words, as they reflect on their experiences in an immersive geoscience field course. The informal interviews conducted for this study serve as one way of helping to partially fill this gap.

Day	Site Name	Age/Period/ Epoch	Era/ Eon	Notes/Features/Sample	Story
1	Upper loop	13Kya; Holocene/Late Pleistocene	Cenozoic	Glaciers; cirques; ridges; kettle lakes; meandering rivers	Glaciers cover western Colorado. As they recede, they leave behind moraines and U-shaped mountain valleys
1	Lateral Moraine	10Kya; Holocene/Late Pleistocene		Glaciers melted due to climate change (over 20K yrs., not our *lifetimes* like current CC).	
1	Anthracite Mesa	15-20Mya; Miocene		135Mya Cretaceous Sea; Superposition; Rolling hills -> Mancos shale	Widespread volcanic activity including at the nearby (30 miles) San Juan and West Elk sites. Hellfire rained down on the area
1	Slate Creek	28-30Mya; Oligocene		Slate; Quartz; Sill with Iron Pyrite; Intrusion with aplite	
2	Curecanti Recreation Are	30Mya; Oligocene		Breccia (angular); pyroclastic flows; W Elk Volcano; Little Hoodoos (Basalt capped ash)	
2	West Elk Loop	28-30Mya; Oligocene		Big Hoodoos; layered by age and volcanic event (San Juan); Welded Ash fall Tuff	
1	Big Rock	35Mya; Eocene		Igneous rock from atop Mt. Crested Butte; Si/O_2; Granite Mondsy Prophrye	
1	Coal mine site	55Mya; Late Paleocene		Anthracite vs. Bituminous; area that would've been swamp of inland Cretaceous sea	As the Western Interior Cretaceous Seaway begins to regress, it leaves behind the beach and adjacent swampy upland.
1	'Beach' site	65Mya; Early Paleocene		Would've been beach of the inland Cretaceous sea; Mesa Verde sandstone	
1	Dinosaur Ridge	135Mya; Cretaceous	Mesozoic	Dakota sandstone	Western Interior Cretaceous Seaway covers the area spreading from the north into Canada, and south to what is now the Gulf of Mexico.
2	Cimarron Canyon	135Mya; Cretaceous		Mancos shale; Gneiss atop shale due to fault line	
3	3 miles S of Almont;	135Mya; Cretaceous/ Jurassic		Morrison formation; floodplain environment	
2	Blue Mesa Reservoir	65-150Mya; Cretaceous/ Jurassic		Sandstone; Cretaceous/Jurassic; Dinosaurs get trapped during flood events	Dry/Arid environment gives way to wed/humid climate. Dinosaurs roam this part of Western Colorado that courses with rivers, and eventually succumb to flooding events.
1	Red Rocks	145-200Mya; Jurassic		Morrison Formation	
3	One mile south of Almont	200Mya; Triassic		Morrison (fluvial; Jurassic) sits above Entrada sandstone (desert; wind deposited) sits above Schist (Precambrian); unconformity; where is missing stuff?	
3	Cement Creek	240-400Mya; Pennsylvanian/ Mississippian	Paleozoic	Leadville limestone; sits below Mancos shale	Uplifting due to plates crashing together leads to the formation of the Ancestral Rockies. Erode over time due to weathering.
3	Lunch rock	240-400Mya; Pennsylvanian/ Mississippian		Conglomerate (rounded); erosional remnants of the Ancestral Rockies	
2	Hartman Rock	1.4-1.7Bya; Precambrian	Precambrian	Granite batholith; magma chamber; tectonic plates ride over each other	Primordial earth consists of the parent material that makes up the basement of Earth's crust.
2	Pine Creek Trailhead	1.7 Bya; Precambrian		Basement rock; Headwaters of the Black Canyon of the Gunnison; devoid of fossils; Gneiss (dark with quartz banding; metamorphic)	
2	Bottom of Cimarron Canyon	1.4-1.7Bya; Precambrian		Schist (metamorphosed sedimentary rock/mud); clay -> mica (shiny)	
2	Black Canyon of the Gunnison	1.7 Bya; Precambrian		Gneiss (black) topped with Entrada formation (white)	

Figure 1. Sites visited on first three days in the field mapped onto the geologic time scale

METHODS

Setting & Participants

The course described here took place during July 2018 and was based out of the remote ski village of Mt. Crested Butte, Colorado. Two veteran science education professors were responsible for leading the field course. A graduate teaching assistant (TA) who had previously taken the course helped co-teach several lessons in the field and led group study sessions in the evenings with the participating students. Twenty-two students participated in the weeklong field course, 14 of which were female. Most of the participating students were preservice elementary, and secondary science teachers seeking undergraduate, and master's degrees in elementary and secondary science education. One geoscience undergraduate, and one student majoring in special education were also enrolled in the course. A graduate research assistant was embedded with the group to observe and interview students enrolled in the course about their experience and monitor the teaching practices of the two lead instructors.

Data Collection

In addition to the exit interviews that participating students completed with the lead instructors to assess their geology content knowledge, a secondary from of assessment was included to gauge how the course impacted students' conceptions of science, learning, and teaching. On the final day in the field, prior to the exit interviews conducted by the lead instructors, the graduate research assistant moved from vehicle to vehicle in-between field site visits, conducting informal interviews with the participating students. Data was collected using convenience sampling (Miles, Huberman, & Saldaña, 2014) based on whoever happened to be willing to talk, and who was riding in a vehicle at a given time. Students were not required to participate in the informal interviews, and some chose not to respond to every prompt.

During the informal interviews, students were faced with a series of prompts asking them to reflect on their big takeaways from the field course, how the weeklong experience changed the way they thought about science in general and geology more specifically, and what stuck out about the student-centered approaches to teaching they had observed. Based on the differences in drive time between field site locations, some of the informal interviews did not include the full range of prompts. The informal interviews resulted in over 120 minutes of recorded audio that was then transcribed by the 1st author. No attempt was made prior to the weeklong field study to collect information from the participating students related to their existing geoscience content knowledge, ideas about learning and teaching, or conceptions of NOS.

Data Analysis

Transcripts from the semi-structured interviews served as the unit of analysis for this study. First-cycle descriptive coding (Saldaña, 2015) of the interview transcripts was carried out by the 1st author to uncover emerging themes in students' spoken responses, while identifying those examples that offered clear evidence of thoughtful reflection by the participating students. Initial analysis resulted in simple, single-sentence responses being removed from the data set to focus on the lengthier, more thoughtful student reflections. Primary data analysis also allowed for the identification of those interview prompts that tended to offer students more opportunity for deeper thought, and space to fully reflect on the weeklong field experience. It was determined that only student responses to the following prompts would be considered for secondary analysis:

- *What did you think about the approach to teaching adopted by the lead instructors?*
- *How have your ideas about science changed as a result of the weeklong field experience?*
- *What stuck out to you about field sampling and building your rock box?*

Responses to these prompts were coded as 'Teacher Moves', 'Science Ideas', and 'Rock Boxes', respectively, and analyzed further to detect evidence of students' NOS conceptions.

Of the 22 students who participated in the course, informal interview responses from seven students were chosen as the unit of secondary analysis to further characterize the language these students used to describe their experiences and the ways in which their ideas about science, learning, and teaching had changed during their time spent in the field. Representatives of Vehicle #1 included elementary education majors Ella, and Karen (all pseudonyms). Vehicle #2 included Erin, and Monica, both secondary education majors. Vehicle #3 featured responses from Adam, Alison, and David, all secondary education majors. The informal interview

Table 1. Transcript data from informal interviews with students from Vehicle #1

Name	Teacher Moves	Science Ideas	Rock Boxes
Ella	*…they don't give you step-by-step instructions, but they let you kind of lead the activity yourself, and then they'll bring you back together to summarize. But they let you do most of the hands-on learning*		*You can tell them stories about where you collected them, how you collected them, and kids love stories. They can learn better from a story then just spitting off facts, from this pre-made kit that you bought.*
Karen	*They always start out by saying 'what do you see?' It's just for you to get absorbed in the environment and figure out what's going on first, and I like that… it allows you to put together what you've already learned, and each time you're just like putting more and more together when you look at the new scene.*		*Collecting our own rocks is really cool, because if you were to just buy a quartz rock, it's going to be just like straight up quartz. But here you can see what else is in that piece of quartz. It makes more of a connection with what's going on around, and how things are created.*

Table 2. Transcript data from informal interviews with students from Vehicle #2

Name	Teacher Moves	Science Ideas	Rock Boxes
Erin		*This has been an immensely frustrating, but rewarding experience because I tend to be the type of person that would like the summary, and then the breakdown, or the breakdown then the summary. They're not giving us the summary, and I think that is much more of a real-world application.*	*I thought it was just a deeper learning experience. You have to physically handle them, and figure out those connections in order to put them in. No matter how you create those connections you're interacting with those rocks in a deeper way than if you were just taking an exam saying 'quartz is made up of such and such'. It was also good to have that open-endedness which I think some classrooms lack. This way, I organized it how it made sense to me and I'm not in danger of getting any points off, as long as I paid attention and learned the material.*
Monica		*It makes me respect the scientists, and scientists overall even more. Because now you're really seeing what they have to work with. When they go out in to the field to try to figure something out they literally have nothing. And then from nothing, they grab something, you know? They make something.*	*Seeing everything at a grand scale really helped puzzle it together. Like puzzle piece it together. I've read the books and I know the rock cycle, and how rocks change from one thing to another. But seeing it just made it easier, you know?*

responses to the three prompts identified above ('Teacher Moves', 'Science Ideas', 'Rock Boxes') from each of these seven students can be found in Tables 1-3, organized by vehicle number. Responses to each of the selected prompts were analyzed separately to highlight themes in the data, and explore how these students' responses can be used as a means of further investigating the NOS conceptions held by preservice teachers and how those ideas may change as a result of participating in an immersive geoscience field course.

Second-cycle analysis involved the use of In Vivo coding (Saldaña, 2015) to capture participants' conceptions, in their own language, to help tell their stories about their experiences in the field. As a qualitative research method In Vivo coding is appropriate for a wide range of studies, particularly those that prioritize the participants' voices (Miles, Huberman, & Saldaña, 2014; Saldaña, 2015). In Vivo coding uses words and phrases from the participants' responses to generate a set of codes that can be further condensed into categories, which shape the themes and theories developed through qualitative analysis. An example of In Vivo coding from Monica's interview transcript in response to a prompt about building her rock box can be seen in Table 4. Here, Monica's response to the 'Rock Boxes' prompt was broken up into approximately sentence-length segments with each piece receiving a code based on Monica's own words. The data in Tables 1-3 were analyzed separately resulting in over 125 unique In Vivo codes that were then further categorized based on the nature of the code. It was apparent from this set of codes that participants' responses tended to clump around five categories that focused on different aspects of the nature of science and the respondents' feelings about participating in the weeklong geoscience field course.

Table 3. Transcript data from informal interviews with students from Vehicle #3

Name	Teacher Moves	Science Ideas	Rock Boxes
Adam	*Sometimes my questions were answered, but the big ones they made me work for it, which for me, as a student, is frustrating because I just want to know what's the answer. But it's more beneficial for me to work for it, earn it, and then understand it as a result, rather than just knowing facts. That was frustrating, but really cool to experience because I'm used to just reading a textbook.*	*I'm used to going to a textbook and saying oh well there's the answer. There's the entire history of Colorado, which, I think, was chapter two in our textbook. I'm used to doing that. This class has a.) Showed me that someone had to figure this out in the first place. So what we're doing is what people had to do if they didn't have textbooks to turn to. I am used to going to the textbook and getting the big picture and then honing in on all the subsections and this is the opposite. So it stretched me as a learner to try and do the opposite. I'm not going to get the answers right away. I'm going to have to piece it together. So it was a good challenge.*	
Alison	*Let the students have their curiosity first. They let us look around a little bit and touch and feel and get our curiosities up, and try and have us understand first what we think we're seeing and then again, they still don't even give us the answers at the very end they ask us what we're seeing.*		*A lot of the sandstones, the primary is silica. You hear silica or you see it on a periodic table and kids are kind of like 'okay, whatever, I don't really know what that means'. But you could pull out all these different sandstones. It's cool to think that from one geoscience class, I can take that into my chemistry classroom and actually show them what some of these elements can make up, and if you combine them together, what they could actually look like in real form.*
David		*I took nature of science already, but if I didn't … with the story at first… a lot of people come in here and think that the textbooks have the answers, and that's not what it is at all. We have bits and pieces of the story but we could honestly be completely wrong… There are a lot of things that have been in textbooks for years that later on got disproven. We're showing, with unconformities and stuff, we don't know, but we're trying to give our best option of what could have happened best based on the evidence that we have.*	*… if I ordered that rock box it would just be a list of names in my head. I'll know what equals what but I won't know the meaning behind it. This way, I know where we chipped that rock off from. I know what that rock looks like in the mountains versus someone giving me a rock and saying these are in the order of age… Now we're able to see. We're chipping things from different parts and we know how all of it comes together.*

Table 4. In Vivo coding of Monica's response to a prompt about field sampling and building her rock box

Transcript Text	In Vivo Code
Seeing everything at a grand scale	"Seeing at a grand scale"
really helped puzzle it together.	"Puzzled it together"
Like puzzle piece it together.	"Piece it together"
I've read the books and	"Read the books"
I know the rock cycle,	"Know the rock cycle"
and how rocks change from one thing to another.	"How rocks change"
But seeing it just made it easier, you know?	"Seeing made it easier"

FINDINGS

Initial coding of seven students' responses to three of the informal interview prompts revealed the presence of five emerging themes that centered around the tentative, empirical, and creative nature of science knowledge, sources of authority, and feelings associated with participating in the course. Each of these five big ideas will be treated separately, with a focus on the language students used to express their thoughts about the weeklong field experience, and the impact the course had on their ideas about NOS and teaching. From these findings an attempt will be made to characterize students' conceptions of NOS using Khifshe's (2008) developmental model of NOS understanding.

Students' Conceptions of NOS

While there is at present no concrete definition of NOS that all science educators agree upon, there is wide acceptance in the literature of several key components that make up an informed conception of NOS. In their development and validation of an NOS assessment tool, Lederman et al. (2002) identified several aspects of NOS and scientific knowledge: science knowledge is tentative; empirical; theory-laden; the product of human creativity; and socially embedded. Additional components of their NOS model include differentiating between observation and inference, the myth of a universal scientific method, and the relationships between scientific laws and theories. Using this model as an analytical framework helped identify instances where participating students revealed their NOS conceptions and how those ideas may have shifted as a result of taking the course. Of the components identified by Lederman et al. (2002), three were shown to exist in participating students' responses to informal interview prompts: scientific knowledge is empirical, creative, and tentative.

Empirical NOS

Developing an informed view of NOS requires an understanding that science knowledge is constructed using empirical, evidence-based studies that rely heavily on observation and inference making. Many of the In Vivo codes focused on what the students saw, observed, touched, and sampled in the field, including: "Grab something", "Physically handle", "Really seeing", "Seeing made it easier", and "Chipping things." These examples from the students' responses indicate that they are aware of, and place value in the role of observation as an epistemic tool. They demonstrate an awareness of the importance of observation as a means of building evidence and recognize various benefits of being in the field to collect samples and build their own rock boxes, as opposed to acquiring a rock box from a third party. In her response to the prompt asking about the teaching methods she observed, Alison's comment *'They let us look around a little bit and touch and feel and get our curiosities up'* emphases the importance of our senses as tools to assist with the development of scientific knowledge. When asked about building her own rock box, Erin replied *'You have to physically handle them, and figure out those connections in order to put them in'*, as she expressed the value of collecting her own samples, and being able to handle them as they existed in the field. These and other responses provide evidence that participants understand the empirical nature of scientific knowledge, and their experience in the field appears to have provided them with numerous examples of how this aspect of NOS can be used as a learning tool in the classroom.

Creative NOS

In addition to being empirical in nature, science educators also see scientific knowledge as being the product of human innovation, imagination, and creativity. Scientific knowledge does not exist outside of the human minds that invent it, and there are no absolute truths to be discovered objectively. Rather, humans construct scientific knowledge as we attempt to explain phenomenon that occur in nature and the laboratory, much like the process that students engaged in during the 'Book Bits' activity earlier in the week. Analysis of the informal interview transcripts resulted in several In Vivo codes that centered on the creative aspect of NOS. Examples include: "Puzzle it together", "Make connections", "Bits and pieces", and "Figure it out". In their responses to the prompt asking them to reflect on how their ideas about science had changed, Monica and Adam each gave answers that reflect the creative NOS. In talking about how geoscience knowledge is constructed, Monica replied "*It makes me respect the scientists…. Because now you're really seeing what they have to work with. When they go out in to the field to try to figure something out they literally have nothing.'* Similarly, in discussing what the geoscience field course taught him about how science knowledge is constructed, Adam said that '*…someone had to figure this out in the first place. So what we're doing is what people had to do if they didn't have a textbook to turn to.*' These responses suggest that prior to enrolling in the geoscience field course, neither had given much thought to how scientists come to know what they know. They now appear to have a new level appreciation for the amount of creativity that is required to tell a story as accurately as possible given the available evidence.

Tentative NOS

The third NOS component that students seem to be developing familiarity with deals with the subject-to-change, tentative nature of scientific knowledge. Given that scientific knowledge is evidence-based, and dependent on to the creativity of humans for its construction and development, it makes sense that scientific knowledge is also capable of changing and evolving when confronted with new or conflicting evidence. Indeed, one common thread across science is that knowledge is constantly evolving and open to revision (NGSS Lead

States, 2013). In Vivo coding uncovered a handful of instances where students' language demonstrated an understanding of the tentative nature of science: "Open-endedness", "Disproven", and "Could be wrong." While fewer examples of this aspect of NOS exist in the data, Karen and David each gave responses that demonstrate some level of understanding of the tentative nature of scientific knowledge. In speaking about collecting samples of quartz in the field, Karen replied that '*if you were to just buy a quartz rock, it's going to be just like straight up quartz. But here you can see what else is in that piece of quartz.*' Karen's response suggests that without the opportunity to gather samples in their natural environment, she might have held a misconception about the composition of quartz and other field samples. David, in response to a prompt asking him to think about how his ideas about science changed replied: '*…with unconformities and stuff, we don't know, but we're trying to give our best option of what could have happened based on the evidence that we have.*' In some sense, David's response reflects an informed conception of both the tentative, as well as the empirical nature of science knowledge. Here, David highlights the notion that when confronted with unconformities and other gaps in the geologic record, geoscientists can only hope to fill in the missing pieces using their existing knowledge and the evidence available to them. Their understanding may change as more details come to light, but they'll never know the complete story.

Sources of Authority

In addition to the three aspects of NOS that appeared to emerge during secondary analysis of the interview transcripts, a fourth theme was also present that is closely tied to the nature and development of scientific knowledge. Specifically, there were several examples in the data that shed light onto what participants identify as sources of authority of scientific knowledge. The literature identifies several characteristics that are typical of an informed view of NOS, three of which were summarized above. As we saw, scientific knowledge is empirical, tentative, and the product of human creativity. Researchers seem to agree that students and teachers who are aware of and possess an understanding of these different but interrelated aspects of NOS have, at least on paper, what science educators would identify as an 'informed' conception of NOS (Khishfe, 2008; Lederman et al., 1998). Alternatively, subjects who see scientific knowledge as a static, objective, and absolute body of knowledge, unattached from human creativity possess 'naïve' conceptions about NOS. Though not explicitly attended to in their models of NOS (Lederman, 2006; Lederman et al., 2002; McComas, 1998), the authority in which subjects place their faith when it comes to deciding when to support certain scientific ideas over others would appear to be closely linked to the tentative and creative aspects of NOS, and contributes to our larger epistemologies of science (Driver et al., 1996; Hofer & Pintrich, 1997).

As it relates to the present study, there were notable examples in students' responses that revealed much about where they look to as the authority of scientific knowledge. Examples from In Vivo coding that point to sources of authority include: "Reading a textbook", "Know the rock cycle", "Get the answers", and "Knowing facts". Upon being prompted to reflect on the teaching practices employed by the lead instructors, Ella replied '*…they don't give you step-by-step instructions, but they let you kind of lead the activity yourself….*' Ella's response suggests that she might be less familiar with a learning environment where she's not being guided by a set of cookbook-like instructions to follow but is instead allowed more control over her own learning. In both of his responses to prompts about observed teaching practices and shifts in his ideas about science, Adam repeatedly refers to the textbook as his go-to source of scientific information. '*I'm used to going to the textbook and saying 'oh, well, there's the answer'.*' On the other hand, David, who happened to be riding in the same vehicle as Adam, seemed to feel differently about the authority that resources such as textbooks have to offer. In reflecting on his changing ideas about science, David replies that '*… a lot of people come in here and think that textbooks have the answers, and that's not what it is at all.*' He goes to add that '*…there are a lot of things that have been in textbooks for years that later on got disproven.*' While it wasn't clear if David's response was directed towards Adam, it is evident that there exists a difference in conceptions between participating students about the role that textbooks and others play as sources of authority of scientific information.

Feelings and Emotions

The fifth category that emerged from coding of participants' interview responses dealt with the feelings and emotions that students expressed as they reflected on their experience in the field. Emotion coding (Saldaña, 2015) was used to further analyze those segments of interview transcript that emphasized students' feelings about the course. Examples of codes that fell into this category included: "Made me work", "Stretched me as a learner", and "Frustrating but cool." It is clear upon analysis of these participants' responses that this experience was challenging to them both physically and mentally, and in some cases caused them to reconsider their previous models of learning. When asked how the experience changed her ideas about science, Erin replied '*This has been an immensely frustrating but rewarding experience because I tend to be the type of person that would like the summary, and then the breakdown, or the breakdown then the summary*.' While she found the field course to be frustrating, she goes on to say that she sees this teaching and learning style to be more of a 'real-world' experience, and ultimately found value in an inquiry-based approach to learning. Adam had similar responses when asked about teaching techniques and his ideas about science, reporting that he, too, felt frustrated when he was made to "work" for his answers, adding that *'I'm not going to get the answers right away. I'm going to have to piece it together. So, it was a good challenge.'* These responses reveal that while these participants found the course to be rewarding, it also challenged their existing conceptions of science, learning, and teaching.

DISCUSSION

This research may contribute to the larger body of literature on preservice teachers' NOS conceptions, and the impacts of immersive geoscience field studies, but it is not without its limitations. As mentioned, there was no attempt to collect information from participants prior to the beginning of the field course related to their existing geoscience content knowledge base, and conceptions of NOS, making it difficult to draw inferences about how students' ideas may have shifted as a result of the course. Additional interview data collected prior to and during the week in the field would add validity to the claims we're making here about the impact that such an experience can have on participants' conceptions of NOS, learning, and teaching. The small number of participants, lack of control group, and sampling based on convenience also limit the findings of this study, containing any inferences that we can draw from our work to the sample of participating students. We do believe that, to the extent that the students enrolled in the geoscience field course described here are comparable to the larger population of preservice science teachers, the findings reported on in our work may be informative to broader preservice teacher preparation efforts.

Through the present study we have been able to demonstrate that an immersive, field-based geoscience course tailored to prospective science teachers does show some potential for stimulating growth in participants' conceptions about the nature of scientific knowledge, learning, and inquiry-based approaches to teaching in the science classroom. Using In Vivo coding, transcripts from interviews with participants revealed evidence of an understanding of the empirical, creative, and tentative aspects of NOS, hints about what students see as figures of authority when constructing scientific knowledge, and their feelings and emotions about the immersive field study. With respect to the research question, it seems that participating in the weeklong geoscience field course did have some impact on these preservice teachers' conceptions of science, learning, and teaching as evidenced by the use of language like "Stretched me as a learner", "Immensely frustrating but rewarding", and "Good challenge" when describing their experiences. Other responses suggest that participants are beginning to see that learning is more than just "spitting off facts", assessment is more than "just taking an exam", and teaching is more than simply providing "step-by-step instructions" suggesting a shift towards a more informed view of NOS.

Other evidence that students may be reconsidering alternative models of thinking and learning about science comes in the forms of responses like '*it's more beneficial for me to work for it, earn it, and then understand it as a result, rather than just knowing facts'* when Adam reflects on inquiry-based teaching. He seems to be suggesting that there is more to science learning than simply picking up a textbook and memorizing the "facts." Likewise, when Erin talks about the benefits of building her own rock box, she makes the claim that '*you're interacting with those rocks in a deeper way than if you were just taking an exam saying quartz is made up of such and such.'* Her decision to use the word 'just' when referring to assessments that rely on simple recall demonstrates that she sees the benefit of alternative forms of assessment that go beyond simply asking students to memorize content.

Without having any direct evidence of NOS conceptions held by participants prior to the weeklong field course, it is difficult to say how these students' conceptions of science knowledge shifted as a result of their participation in the course. Khishfe (2008), in her work with middle school students, demonstrated that participants' views about the tentative, empirical, and creative aspects of NOS could be shown to evolve along a continuum prior-to, during, and following explicit instruction of NOS principles, from naïve conceptions of NOS to more informed views through an transitional middle phase. While it is impossible to demonstrate such evolution in beliefs based on our limited data set, there is potential to begin characterizing the NOS conceptions held by these participants using Khishfe's model. Of the seven students whose responses were detailed in this study, only David appears to have what Khishfe might identify as an informed view of NOS. His responses clearly indicate an understanding and appreciation of the tentative aspect of NOS, something that seems to be lacking in most of his classmates' replies. This may be due in part to David's prior course work on the nature of science as he is quick to point out when being prompted to reflect on his ideas about science and how they might have changed following his experience in the field.

On the other hand, while David appeared to be the only respondent who clearly conceptualized the tentative aspect of NOS, many of his classmates' responses indicated evidence that they too have a basic understanding that scientific knowledge is empirically based, and the result of human creativity. One might hesitate to characterize any of the participating students as having a naïve conception of NOS based on Khishfe's criteria. Even Adam, who time and again mentions his tendency to rely on the textbook as a source of authority for scientific knowledge appears to be open to considering other lines of scientific inquiry. Despite his insistence on the textbook being a place where answers can be found, the tenor of Adam's responses would seem to suggest that going forward he's open to placing less authority in the textbook and engaging in the process of coming to understand a concept through his own inquiry. This may be evidence that Adam might be somewhere in the transitional phase of Khishfe's continuum between a naïve and an informed conception of NOS.

IMPLICATIONS

This research appears to support previously reported findings (Abd-El-Khalick & Lederman, 2000; Lederman, 1992) that an explicit approach to covering topics related to the nature of science in preservice teacher preparation programs can lead to growth in participants' understanding of the tentative, creative, and empirical aspects of NOS. While these terms (tentative, creative, empirical) were not explicitly used as anchoring vocabulary throughout the week spent in the field, engaging students in the 'Book Bits' activity and discussion that followed at the beginning of the field study did authentically set the stage for the week, orienting students to the practices that scientists engage in as they attempt to construct theories from observations, inferences, and other lines of evidence. They lived out this same process over several days in field collecting samples and piecing together evidence to tell their version of a story that explains Western Colorado's geologic past. Some participants not featured in this study commented that they saw the 'Book Bits' activity as a "shrunken-down" version of the entire week, as they put together the story of Colorado's geology through site visits, sampling, and stories told by the lead instructors. We see the practice of using storytelling in the classroom and the field to be a helpful teaching tool, and the findings reported on here provide evidence as to the effectiveness of a 'science as storytelling' approach. This has implications for teacher preparation efforts in other content areas outside of geology as well. While it is true that geoscientists rely heavily on piecing together evidence to help tell a story, the process of constructing scientific knowledge has common threads that extend beyond Earth science into the realms of the biological, chemical, and physical sciences as well. Activities like 'Book Bits' coupled with an immersive field experience such as the one described here have potential in other educational contexts beyond the development of pre- and in-service teachers, with the opportunity to help shape the conceptions of NOS held by all students.

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Notes on contributors

Nathan Anderson Quarderer – Northeast Iowa Community College, Calmar, Iowa, USA.

Ted Neal – University of Iowa, Iowa City, Iowa, USA.

John Dunkhase – University of Iowa, Iowa City, Iowa, USA.

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