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A Case of Fragmented High School Earth and Space Science Education in the Great Plains: Tracing Teacher Certification Policy to Students' Access

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ABSTRACT

Although U.S. high school students' access to Earth and space science (ESS) varies widely from state to state, nationally, ESS content is the most neglected area of science education and scientific literacy. States have been considering whether they will formally adopt, or less formally adapt, the new national science education standards, the Next Generation Science Standards (NGSS), which have been carefully developed and articulated in conjunction with state education leaders. However, there are many challenges with which states, school districts, and teachers must grapple to enact standards-aligned ESS science lessons. This study of one Great Plains state investigated how school districts provide ESS education at the high school level and to what degree is ESS being taught by qualified teachers. We found that 76% of districts added ESS topics to existing physical science and/or biology courses rather than offer a stand-alone ESS course. During the eight-year period investigated, the state awarded 901 science teaching endorsements to either new secondary teachers of which only 3.3% were single-subject ESS endorsements. In Phase I and II of our study we found that only 7% of science teachers teach ESS with an ESS endorsement versus a general science or other science subject area endorsement. When teachers teach ESS out-of-field they lack the confidence and subject matter knowledge to teach effectively using inquiry-based approaches and are less likely to recognize misconceptions and oversimplification of ESS content. © *2017 National Association of Geoscience Teachers*. [DOI: 10.5408/17-253.1]

Key words: Earth and space science education, secondary science, science teacher endorsement, state science teacher licensing policies

INTRODUCTION AND RATIONALE

Earth and space science education (ESS) is vital to developing students' understanding of how environments, systems, and geologic processes affect humans and vice versa. However, most Americans' formal learning of ESS ends by grade 8 (National Association of Geoscience Teachers [NAGT], 2012). For decades the issue of U.S. students' limited opportunity to learn ESS in most states has been described by many researchers (e.g., Mayer, 2002; Ridky, 2002; Lewis, 2008; Lewis and Baker 2010). Despite limited access to ESS, this domain of science has been included consistently in national science education standards (American Association for the Advancement of Science [AAAS], 1994; National Research Council [NRC], 1996; Achieve, Inc., 2013) and described as a critical part of students' scientific literacy (AAAS, 1989; NRC, 2012). State, national (e.g., National Assessment of Educational Progress [NAEP]), and international large-scale assessments (e.g., Programme for International Student Assessment [PISA]) routinely include ESS content. Although U.S. high school students' access to ESS varies widely from state to state, nationally, ESS content is the most neglected area of science education (American Geological Institute [AGI], 2013; AGI, 2015).

In 2001, representatives from all areas and levels of the geosciences engaged in a National Science Foundation (NSF) funded national conference on the state of geoscience education. They developed important long-term recommendations and a vision for improving the state of geoscience education (Barstow and Geary, 2002). The participants generated a set of 10 recommendations in the area of policy and systemic reform for advocating for and elevating the status of ESS education. These ambitious recommendations concerned policy at the federal, state, and district levels. At the federal level the report authors recommended that federal funds or agencies should: (a) "support ESS education initiatives; (b) support partnerships for ESS education reform; (c) federal agencies involved with ESS research should support and require links with both formal and informal education; (d) establish points of contact in each of the federal agencies; (e) support a program to evaluate the effectiveness of ESS education as an annual "snapshot" of progress" (Barstow and Geary, 2002, 28–29). The authors stated that at the state level that all states should: (a) "offer ESS curricula and review their ESS education frameworks to ensure that they reflect revisions in content and methods in the NSES (1996); (b) review their assessment practices to mirror these frameworks; (c) create incentive programs to produce, recruit, and retain ESS teachers as well as provide professional development; and (d) establish state-based alliances for ESS education in every state" (Barstow and Geary, 2002, 29–30). Finally, the authors recommended that districts should implement ESS education reforms through local policy and practice in alignment with state and national standards (Barstow and Geary, 2002, 30). These recommen-

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dations address all levels of the educational system that have the potential for improving ESS education.

In 2010, a second ESS education summit was organized and held in Houston, Texas, by the American Geological Institute (AGI) and supported with a grant from the NSF (AGI, 2011a). At this meeting 10 guiding principles were proposed:

1. The geoscience community must speak with a common voice.
2. The geoscience community needs a public relations campaign for ESS education.
3. ESS education needs to be inclusive.
4. Teacher professional development for ESS must be organized nationwide.
5. There needs to be a state-level network to deal with crises in ESS education.
6. A nationwide campaign is needed to encourage institutions of higher learning to accept ESS high school courses as laboratory science courses.
7. The geoscience community must be politically savvy in ensuring ESS inclusion in national and state standards.
8. The geoscience community needs to work with guidance counselors and parents to raise the profile of ESS in schools for subject literacy and as a career option.
9. The AP Earth Science Exam can legitimize ESS in schools.
10. Look to the International Earth Science Olympiad as a public relations opportunity for ESS education and a chance to engage students at all levels in solving local geoscience problems. (AGI, 2011a, 2)

Each of these guiding principles was crafted in response to common and persistent challenges that ESS education has faced, for instance, high standards for ESS education, equitable education for diverse students, regular and accessible teacher professional development, and equal emphasis on ESS education, along with domains of life and physical science.

Recently the National Association of Geoscience Teachers (NAGT, 2012) issued a position statement on high school ESS instruction in support of the conference priorities. In this statement the NAGT called for "robust Earth science education in high school and rigorous training of Earth science K–12 teachers." Advocates of ESS education have ensured that this domain of science has an equal presence in the new Next Generation Science Standards (NGSS) national standards (Wysession, 2013). With new standards that have a stronger emphasis on ESS and ever-increasing natural disasters related to global climate change (Achieve, Inc., 2013) it is continuing to be more important than before to understand how to effectively advance ESS education in the U.S. and around the world.

Earth and Space Science Literacy and Misconceptions

ESS education is vital for all K–12 students in their process of learning about science and to develop scientific literacy (Mayer, 2002). When students understand the world around them and how humans interact with different Earth systems that produce phenomena such as earthquakes, flooding, and climate change, they are potentially more empowered to be scientifically literate citizens engaged in decision-making about, for instance, resource management, land use planning, and energy conservation. From a national survey commissioned by the California Academy of Sciences (2009), 47% of U.S. adults do not know how long it takes for the Earth to revolve around the sun, 41% of them think that humans and dinosaurs lived at the same time, and only 47% can roughly approximate the percent of the Earth's surface that is covered with water. The survey also found that only 21% of U.S. adults could answer all three questions correctly. More recent surveys (Leiserowitz et al., 2010; National Science Board, 2014) offer similar results. Geoscience misconceptions are very common. Francek (2013) conducted an exhaustive search of educational research and summarized over 500 ESS misconceptions of which about 40% were revealed when focusing on middle and high school students' knowledge. Clearly, there is a great need and opportunity to rectify students' understanding of ESS and the NGSS are designed to provide performance expectations to do so.

States have been considering if they will formally adopt, or less formally adapt, the new national science education standards, the NGSS (Achieve, Inc., 2013), which were carefully developed and articulated in conjunction with state-level educational leaders. However, standards are insufficient in and of themselves without reliable access to effective education and qualified teachers. There are many challenges with which states, school districts, and teachers must grapple in order to provide reliable access to standards-aligned ESS science lessons. Without standards-aligned ESS instructional and assessment practices, U.S. citizens will continue to hold misconceptions and lack critical thinking skills to make informed decisions about natural resources and human interactions within their local and global environments. Much more work needs to be done to investigate how state- and district-level decisions about ESS education are made and affect classroom instruction as this is a conspicuous gap in educational policy-to-practice research (Coburn et al., 2016).

As with all science education, ESS education is complex and situated within nested contexts from national standards to classroom teacher practices (Fig. 1). Although a vision of ESS literacy has been outlined in the NGSS at the national level, states are free to decide to what degree they will adopt these standards as their own. Once state standards are established then all public school districts must decide how they will address such standards through K–12 science programs and staffing. Such nested, "vertical," decision-making and contexts, i.e., classrooms within schools, schools within districts, districts within states occur within hierarchical organizational levels. Horizontally across the same level, ESS education varies greatly as the interpretation of policy and decision-making vary from state to state, district to district, school to school, and classroom to classroom. Within these systemic structures, students experience ESS curriculum and instruction provided by their science teachers.

This study was designed to provide an initial bridge to understanding how state-level teacher licensure policy, endorsements, and district-level staffing decisions about high school ESS occur. In the following section we review research on secondary ESS education, the historical lack of widely-available, highly-qualified ESS teachers, and the

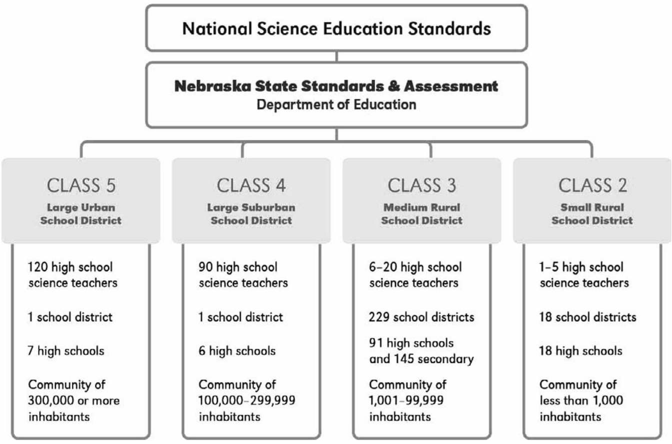


FIGURE 1. Horizontal and vertical organization of the Nebraska educational system from national standards to classroom teachers.

problem of staffing high school ESS content delivery and/or courses with qualified ESS teachers. All of these issues must be considered with respect to the hierarchical and complex educational system.

Background Literature

Status of Secondary Earth and Space Science Education

Since its inception in the 1960s formal ESS education has struggled to gain an equal footing in K–12 education with the life and physical sciences (Ridky, 2002; Dodick and Orion, 2003). ESS is the least studied, following life science and physical science, with only 11% of high school students taking an ESS course prior to graduation (AGI, 2011a; Nord et al., 2011), while most (88%) students take a life science course (Barstow and Geary, 2002) to meet their high school science requirements. That stated, access to ESS courses varies greatly from state to state. For example, unlike nearly all other states, New York has, on average, about 70% of its high school students enrolled in an ESS course and for decades has had an ESS Regents Exam that counts toward students' high school graduation science requirements (AGI, 2002). Such an exam provided motivation for schools to provide Earth Science courses and students to take them.

In both the Benchmarks for Scientific Literacy (AAAS, 1994) and the National Science Education Standards (NSES; NRC, 1996) ESS has an equal status among its sibling science domains. The authors of the NSES (1996) stated unequivocally that all three domains of science should receive equal treatment K–12. The NGSS documents presented the performance expectations for 13 disciplinary core ideas, four in physical science, four in biological science, three in ESS, and two in engineering; although "energy" from the physical science groups could be considered entirely cross-disciplinary. The design of the NGSS frameworks reflected a philosophy of science education that focuses on coherence, thus its authors chose "a limited set of core ideas in order to avoid the coverage of multiple disconnected topics—the oft-mentioned mile wide and inch deep curriculum. This focus allows for deep exploration of important concepts, as well as time for students to develop meaningful understanding" (NRC, 2012, 25). Once the NGSS were released for adoption many resources were made available to help states, school districts and teachers reconsider their K–12 science education programs.

One such resource, a set of domain models, has been offered on the NGSS website and its accompanying mobile app. In this set of domain models there is a middle school ESS model, but no comparable high school ESS domain model. Rather the ESS performance expectations were divided among the biology, chemistry, and physics models for those school districts that have been resistant to changing their traditional course sequences (M. Krehbiel, pers. comm., 2/9/17). From a negative point of view, this suggested curricular model may reflect the historical and continued marginalization of ESS, school districts' resistance to change, and the typical short supply of highly-qualified ESS teachers. Curricular maps like this may inadvertently perpetuate continued secondary status rather than ESS as a full-fledged domain of its own that could be used as a conceptual framework for systems science education. Alternatively, when we return to the policy and guiding principles from the AGI reports (Barstow and Geary, 2002; AGI, 2011a), specifically #7, "The geoscience community must be politically savvy in ensuring ESS inclusion in national and state standards," it can be argued that the NGSS materials that have been offered in this fashion may serve to either placate or minimize the possibility of elimination of ESS standards altogether, and perhaps it is better to be accepted under any model than be eliminated or ignored altogether. To an extent this is speculation on our part and without further, more careful investigation it is difficult to know how this suggested model is being perceived by school districts and teachers. We summarize the current situation of ESS teachers next.

A Need for Qualified Earth and Space Science Teachers

Although the numbers of high school ESS students nationally reveals a wide range of ESS enrollments in different states, it does not explain why ESS has been the most marginalized of all three science domains. There are many possible reasons, but one major factor could be the lack of a supply of qualified science teachers who can teach ESS and are in and of themselves a critical mass of professionals to advocate for ESS at grades 9–12. With the NGSS and a national call for stronger ESS education, many more out-of-field science teachers may be called upon to teach ESS content, especially if the "bundling model" by the NGSS resource developers gains momentum.

Highly-qualified teachers are defined as those who have a major in their field. Thus, ideally ESS teachers would have earned an undergraduate degree in the geosciences. Comparatively, the pool of biological science majors is much larger than that of the geosciences. NSF (2017) reports that in 2014 there were a total of 109,520 new biological sciences bachelor degrees awarded as compared with only 6,730 degrees in the geosciences. Thus, there is a greater than 10-fold pool of biology majors than geoscience majors who could become teachers.

Teacher certification in the United States is not defined consistently due to the priority that states are given for local control. Historically, in response to the federal funding requirements of the Smith–Hughes Act of 1917, by 1921 most U.S. states were issuing specific licenses for teachers to teach specific subject areas, and "usually, training requirements were higher for each new specialized certificate, but in some states they were based on subject-specific examinations, with or without prerequisite training" Angus, 2001, 19). Each state sets minimum requirements for a secondary teaching license in science and how they group teachers' knowledge in fields, such as "science," versus individual subjects, e.g., biology, is different from state to state. Compounded with this is the fact that while individual teacher preparation programs must meet the state minimum they can still set higher requirements. Most states offer the specific subject endorsement, typically for the high school level (Olsen et al., 2015). However, Olsen et al. (2015) reported that in 39 states in the U.S., teaching chemistry, physics, Earth Science, or biology at the high school level can occur without a license in that subject area. Although this statistic may be shocking, when "states offer multidisciplinary licenses, usually called general science, all science, basic science, integrated science, physical science, or simply 'science'" (Olsen et al., 2015, 19) it does not mean that teachers are in-field qualified to provide high quality education in the classes that they are assigned to teach. For example, Ingersoll (1999) conducted a study of in- and out-of-field teachers and found that on average about 20% of secondary science teachers were teaching out-of-field. More recently, the 2012 National Survey of Science and Mathematics Education (Banilower et al., 2013) reported that 61% of high school science teachers and only 26% of middle school teachers reported having a degree in a science area. In our study, the report's authors found that only 42% of the nation's high school Earth Science teachers have had no coursework beyond the introductory level in ESS.

Along with the introduction of Earth Science as a science topic in the 1950s and 1960s, grant-funded teacher professional development was offered to assist teachers in learning the new content. One such project, the Earth Science Curriculum Project established a center in Boulder, Colorado, in 1963, that supported national curriculum and instruction efforts with textbook ("Investigating the Earth") and laboratory manual development, and regular newsletters (Heller, 1963). As Earth science education gained greater interest throughout the 1960s, the Earth Science Curriculum Project staff predicted in 1966 that there would be a need for 20,000 Earth science teachers by 1970; at the time, there were only about 6,000 to 7,000 "more or less qualified earth science teachers" (Romey, 1966, 89). Nearly 50 years later, with about 15,600 teachers assigned to teach ESS, we still have not reached the estimated numbers needed in 1970 to teach ESS (Lewis, 2008). By comparison, there are over 52,000 biology teachers assigned to teach 88% of high school biology students (Blank et al., 2007). However, these figures are from school staffing surveys, not state endorsement records, thus we do not know what percentage of these teachers assigned to teach ESS are highly qualified to do so.

Consequences of Teaching Out-of-field

When teachers teach out-of-field they often lack the subject matter knowledge to question information that is presented in an authoritative vehicle such as a textbook. Having a major or a graduate degree in a subject contributes to a teacher's effectiveness and has been linked to higher student achievement (Chaney, 1995; Goldhaber and Brewer, 1997, 2000). Teachers rely upon science textbooks as a key source of information (Elliott and Woodward, 1990). However, King (2010) conducted an analysis of misconceptions in ESS textbooks used in England and Wales and found that among these 51 texts that on average there was a rate of one error per page. Additionally, self-efficacious teachers are typically more willing and motivated to incorporate constructivist approaches (i.e., inquiry) to teach science (Jones and Carter, 2007). These teachers are termed "producers" and view themselves as learners who recognize a need for change in the traditional way science has been taught (Jones and Carter, 2007, 1081). On balance, an adaptive teacher with strong content knowledge is more likely to be a more effective teacher.

Teachers motivated to improve their instruction may seek teacher professional development to learn to use predeveloped quality curriculum, similar to that of the historical Earth Science Curriculum Project, or by taking more coursework in ESS subjects, or attending ESS-focused workshops when they attend conferences sponsored by such organizations as the National Science Teachers Association (Wallace and Loughran, 2012). Such efforts are important to improving teachers' content knowledge and if such professional development is provided over a sustained time period teachers' new knowledge can have transferable results to the classroom in terms of more effective teaching (Blank et al., 2008).

Rationale for Study

There are few studies that have investigated the effect educational policy has on how schools and teachers structure and enact science courses and teaching practices. Thus, generating more detailed information about science teachers' qualifications and districts' decisions about how to staff and support high school ESS education is only a first step toward producing insights into how students' access to standards-aligned ESS education is controlled and structured. Our study seeks to explore how one state's educational policy translates into grades 9–12 science program design and school-level staffing decisions regarding the teaching of ESS content.

Methodology and Context of Study

The problem of how ESS education is enacted at the high school level in one state can be addressed by the using a case study approach (Yin, 1994). A case study approach is often adopted to address problems, situations, or issues that would benefit from deeper insights. In this exploratory, descriptive study, we define the case as high school students' access to ESS education in the state of Nebraska taught by qualified ESS teachers. Although Nebraska tests ESS content at grade 11, includes ESS content in its state standards, and offers a single-subject endorsement in ESS, this does not inform us as to how ESS curriculum and instruction is being designed and delivered to Nebraska high school students. By using a case study approach, we investigated the questions: (a) *How do school districts provide ESS education at the high school level?* (b) *To what degree is ESS being taught by qualified ESS teachers?* and (c) *How do high school students perform on the ESS portion of the state science test?* We describe our methods as follows.

Research and Analytical Methods

We used two different successive methods of obtaining information about high school ESS education in Nebraska and refer to these as Phase I and Phase II throughout the report. Two phases using multiple methods were necessary to provide credibility to the study (Erickson, 1986; Erickson, 2012). In the first phase of the study, we used qualitative research methods (Miles and Huberman, 1994), specifically, interviewing to enable us to describe the phenomenon of when and how ESS topics and curriculum was being taught and by whom. Purposeful and snowball sampling (Noy, 2008) were used to identify interviewees who would be able to describe when high school students had access to ESS content in their high school's science program and what specific teaching endorsements those science teachers held. In addition to our categorical analyses and descriptive summaries of the interview data we also constructed three vignettes of typical small, medium, and large school districts' approaches to teaching ESS content.

We obtained annual reports from the Nebraska Department of Education on numbers and types of science teaching endorsements, percentages of free and reduced lunch by school district, and state science test scores by district and performed content analyses (Creswell, 2002) of these secondary data sources. The purpose of the content analyses of these secondary data sources was to compile relevant student-level demographic and academic performance information. Building on the findings from the first phase of the study, we used survey methods to increase our sample size in the second phase of the study. More details of the two phases of research follow the section that describes the context of the study. Institutional review board (IRB) approval was granted from the authors' institution prior to beginning the study. Individual school districts' IRBs approved the research before informed consent was obtained from all participants.

Context of Study: Characteristics of Nebraska School Districts

There are a total of 249 public school districts in Nebraska. Overall, Nebraska is a largely rural state with: (a) high numbers of small schools (94% in cities or towns with less than 99,999 inhabitants); (b) high percentages of students who qualify for free or reduced lunch (45%); and (c) low to moderate student racial diversity (Table I). All demographic information is taken from reports produced by the Nebraska Department of Education (2013), ProximityOne (2013), and the Nebraska Department of Economic Development (2011).

Size

Nebraska has school districts in four size classes. Only one school district is in an area with more than 300,000 inhabitants and has seven high schools (equaling 2.6% of the state's high schools including secondary schools for grades 6–12). There is only one district in the next largest category (100,000 to 299,999 inhabitants) with six high schools (that composes 2.2% of the state's high schools). The vast majority (88.4%) of Nebraska high schools are in areas with 1,001 to 99,999 inhabitants with 91 high schools and 145 secondary schools. The final category of high schools ($n = 18$ schools; 6.7% of all schools) is in areas with less than 1,000 inhabitants. As compared with the state categorical percentages the two samples of school districts in our study were comparable with the distribution of school district sizes. This pattern also mirrors the classifications in terms of rural, small town, suburban, and city population densities.

Poverty

Poverty can be assessed in a number of ways; we reviewed county and school district classifications. First, the percentage of poverty at the county level ($n = 93$) averaged 12.9% for all citizens and the state average household income was $50,281. However, an average of 44.9% of all Nebraska public school students are eligible for free or reduced lunch, which reflects the fact that the average poverty rate for Nebraska youth under the age of 18 is higher (17.6%) than that of the average Nebraskan. In Table I we present a comparison of our Phase I and II samples to the state demographics. As compared with the state categorical percentages the two samples of school districts are comparable to the distribution of low to high levels of poverty and average household income, although our sample has more districts in counties with a slightly higher percentage of under-age-18 poverty rate (Phase I average = 21.19%, SD = 5.79%; Phase II average = 18.57%, SD = 5.10%).

Racial Diversity

Nebraska public school districts range in racial diversity from 100% white to 100% non-white, with 68.9% percent of all Nebraska public school students being classified as white, 17.3% Hispanic, 6.7% African American, 2.3% Asian, 1.4% Native American, 0.1% Pacific Islander, and 3.3% as two or more races. Overall, in Nebraska about 31% of its citizens identify as non-white. As compared with the state categorical average of non-white students, the two samples of school districts are generally comparable. We did not weight our averages by number of students at each school, but rather categorized each district by its own percentage of underrepresented students. Our two samples are similar in their distribution of minority students by percentage.

Phase I of Study

Interview protocols were drafted by the lead author for different participants representing the various levels of the educational system (i.e., state science education specialist, district level curriculum coordinator, and science teacher) in the Phase I study. These interview protocols are included in Supplemental Material A (available in the online journal and at http://dx.doi.org/10.5408/17-253s1) of the supplemental materials. The interview agenda was designed to learn more about the details of how ESS content was made available to high school students, and who was assigned to teach those courses, and teachers' credentials to teach ESS, including their professional development experiences. However, a different set of interview questions was written for the state-level science specialist. Those questions concerned topics such as state high school graduation requirements, science teacher endorsement data, design of the state science assessments, and state funding available for teacher professional development in ESS content.

Our investigation began in June 2013 by interviewing a state science education specialist to better understand the overall landscape of secondary ESS education in Nebraska.

TABLE I. Sampled school district demographics and testing compared with state averages.

	Phase I Sample		**Phase II Sample**		**State**	
	Interviewed Districts ($n = 16$)	%	**Survey HS/ Districts** ($n = 48$)	%	**M = 12.9%** ($n = 93$ counties)	%
Poverty Level (% of pop.)						
Low (0–4.9)	0	0.00	0	0	0	0.00
Low–Med (5.0–9.9)	0	0.00	10	20.83	17	18.28
Medium (10.0–14.9)	10	62.50	27	56.25	55	59.14
Mid–High (15.0–19.9)	4	25.00	10	20.83	18	19.35
High (>20)	2	12.50	1	2.08	3	3.23
Average Household Income ($)					M = $50,281	
>60,000	0	0.00	4	8.33	3	3.23
50–60,000	1	6.25	4	8.33	18	16.13
40–50,000	10	62.50	29	60.42	49	52.69
30–40,000	5	31.25	11	22.92	25	26.88
<30,000	0	0.00	0	0.00	1	1.08
School Class Category					($n = 249$ districts)	%
2 (Smallest)	2	12.50	1	2.08	18	7.23
3	12	75.00	47	97.92	229	91.97
4	1	6.25	0	0.00	1	0.40
5 (Largest)	1	6.25	0	0.00	1	0.40
Total % ethnic minority in district					Average	%
0–9.9	9	56.25	28	58.33		31.12[1]
10–19.9	3	18.75	10	20.83		
20–29.9	3	18.75	3	6.25		
30–39.9	0	0.00	3	6.25		
40–49.9	0	0.00	2	4.17		
>50	1	6.25	2	4.17		
Population	($n = 16$)		($n = 47$)[2]		$n = 249$	
Rural	8	50.00	39	82.98	198	79.52
Small Town	4	25.00	7	14.89	39	15.66
Suburban	1	6.25	0	0.00	5	2.01
City	3	18.75	1	2.13	7	2.81
2013–2014 NeSA 11th grade ESS subscores	# of students	% correct	# of students	% correct	# of students	% correct
All	7,268	64.31	2,809	65.74	21,244	64.20
Free/Reduced Lunch						55
White						65
Asian						57
Black /African American						47
Hispanic						53
Native American/ Alaska Native						51

[1] Using only Nebraska constitutes an n of 1, thus we only report average % of minority students; to break into categories data for all 249 districts would need to be listed.

[2] No data for 1 HS as it was in a newly merged district.

This interview, as well as subsequent interviews over the next academic year with district-level science curriculum specialists, science department chairs, and teachers responsible for teaching ESS were conducted one at a time and then analyzed for additional insights and to refine the semistructured interview protocol (Supplemental Material A). Over the next 15 months, a total of 23 interviews were conducted, two with state department of education science specialists and 21 with representatives from a total of 16 school districts. The majority of school district representatives were teachers assigned to teach ESS and were very familiar with the details of how the ESS content was being delivered. These interviewees were also able to identify which teachers at their school had specific teaching endorsements. The number of interviews we conducted and who we interviewed within each district varied from one to four people depending upon the size of the specific district, but the general rule was to talk to as many participants as needed to best understand who was teaching ESS and how ESS content was being delivered to high school students. The interviews were conducted by the first author, sometimes with the second author, either in person, or over the phone. We conducted face-to-face interviews with interviewees at the beginning of the study to ensure that the interview protocol was functioning smoothly and then used phone interviews with those participants at a distance. The interviews were recorded with note-taking at the time of the interview, roughly transcribed for factual information, discussed, and summarized by both researchers to ultimately be able to catalog and compare information across the 16 school districts. All interviews were summarized and verified through the use of member-checking (Creswell and Miller, 2000) at the end of Phase I to ensure that the information was still current and complete. Each interviewee was sent an email in which a summary of their interview was enclosed and asked to read the summary and notify us if they saw any inaccuracies. We received confirmation from all interviewees (or their successors, e.g., the state science specialist).

In order to better understand the rate of production and supply of ESS-endorsed science teachers over time, we also collected eight years' worth of science teacher endorsement records from the Nebraska Department of Education (NDE). Finally, through the NDE's website we were also able to access state science test results by searching for districts. The design of the 11th grade state science test was approximately 25% in each domain of science (Earth and space science, life science, and physical science) for a total of 75%, and the remaining 25% of items focused on inquiry and scientific practices. Additionally, we searched the state department of education's website-accessible database for the 2011–2012 to 2015–2016 science test scores by school district resulting in five-year averages for the Phase I schools. Because the majority of Phase I samples of school districts only have one high school, these science test scores can be considered representative of both school- and district-level performance in ESS. The same was found of Phase II sampled school districts.

Sampling Method

For Phase I, we used a combination of purposeful sampling strategies to select public school districts that would provide a more comprehensive and in-depth description of high-school ESS education in Nebraska. We used maximum variation sampling to match a wide range of potentially different approaches to ESS education. We divided the state into 11 geographic locations (Fig. 2). For recruitment purposes within each geographic segment we selected potential school districts that in combination would be representative of the state in terms of the range of poverty level (e.g., lowest and highest percent poverty rates), median household income, diversity, and school size present in that geographic area. All these demographic categories were further divided into a few subcategories (Table I) to help us finalize a list of possible school districts. We then contacted these school districts for approval. If the district declined our request, we replaced the original targeted school district that declined with another district of similar demographic characteristics. In total we contacted about 40 school districts in order to recruit 16 school districts for the Phase I study and while they are only 5% of the 249 public school districts these schools educate over one-third (34.91%) of all Nebraska high school-aged students. Thus, our sample in Phase I not only represented every geographic region in the sampling grid, but also covered all demographic subcategories. We could not include a district at the Low–Med (5.0–9.9) Poverty Level in Phase I due to a lack of IRB approval from a school district in this category, but we were able recruit 10 school districts at the same poverty level in Phase II.

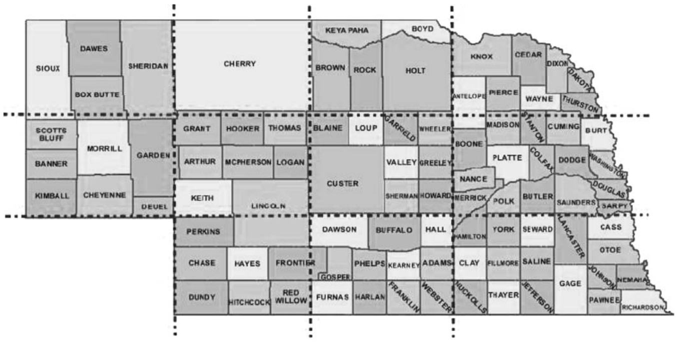


FIGURE 2. Geographic sampling grid for Nebraska school districts shown with dashed lines.

Phase II of Study

In Phase II we developed an online survey (Supplemental Material B; available in the online journal and at http://dx.doi.org/10.5408/17-253s2) based upon our Phase I interview protocol (Supplemental Material A) and preliminary findings from Phase I. The survey questions were derived from the results of the Phase I study and the types and range of information that had been provided by those participants. Some questions concerned the role of the survey taker; other questions asked how many high school science teachers were employed at the school district and how many of the teachers held a single-subject endorsement in ESS. Other questions inquired as to how the ESS content was delivered, for example:

6. How is Earth and space science content taught at the high school level (grades 9–12)?
   (Check all that apply.)

   A. There is a stand-alone ESS course that all students take.
   B. ESS is integrated into physical science.
   C. ESS is integrated into biology.
   D. ESS is integrated into both physical science and biology.
   E. Other: ____________________________

Other survey questions asked at what grade level students take ESS, what textbook was used to teach ESS, what types of materials are used to teach ESS, and what ESS topics are taught. Finally, the survey posed a few questions about teacher professional development in ESS content.

The survey link was sent via email in August and September 2015 to all Nebraska public high school principals, excluding the high schools in school districts that we recruited in Phase I of the study. The survey link could be forwarded to another individual who the principal believed could answer the questions more accurately. Out of the 48 respondents, 21 (43.8%) identified themselves as the school principal, four (8.3%) as an administrator, three (6.3%) as science curriculum coordinator, seven (14.6%) as a general curriculum coordinator, six (12.5%) science department chairs, 15 (31.25%) science teachers, and six (12.5%) who served in more than one role.

The purpose of the survey was to augment the sample size and more broadly verify and/or refute the findings from Phase I. Although we believe the accuracy of the information we obtained through directly interviewing district representatives (science curriculum specialists, science department chairs, and teachers responsible for teaching ESS) directly was generally more reliable (and every district summary was verified through member-checking in Phase I), this was a time-consuming process. We also wanted to construct a case study of the state that was sufficiently representative and the Phase II survey allowed us to obtain information from more school districts. There was a 20.5% return rate from the online survey after three reminders were sent to the survey recipients. Thus, in Phase II we added another 48 school districts to our Phase I sample. We then compared the data we gathered from the survey with the findings from the interviews conducted during Phase I. Through a combination of both research phases we sampled 27% of the state's public school districts that educate 47.9% of Nebraska's high school students. Similar to Phase I, we also collected these districts' state science test scores from NDE's website for the 2013–2014 academic year as well as the demographic information.

Data Analysis

In Phase I, interview summaries were written based on interview notes and recordings. The summaries were later analyzed for the district and school-specific information regarding how ESS content is taught and by which teachers. Core categories of how ESS is taught were outlined based upon the interview data. Secondary data such as demographic information, teacher endorsement data, and state test scores were also used to construct more categories for comparison between states and districts as well as across districts. An Excel spreadsheet/matrix was created to sort preliminary findings for further analysis. In Phase II, the survey data was transformed into an Excel spreadsheet based upon the categorical responses. We calculated the frequencies and compared them with the findings from Phase I.

Results

In response to our research questions: (a) *To what degree is ESS being taught by qualified ESS teachers?;* (b) *How do school districts provide ESS education at the high school level?;* and *(c) How do high school students perform on the ESS portion of the state science test?,* we present the following findings, beginning with Nebraska's supply of ESS qualified secondary teachers.

Production of Qualified ESS Teachers to Teach ESS

Qualified ESS Teachers

In response to our first research question regarding the teaching of ESS by qualified teachers we analyzed the 8-y period from the 2007–2008 to the 2014–2015 academic years that Nebraska Department of Education (NDE) endorsed new science teachers. The NDE awarded 901 science-teaching endorsements and of these 901 endorsements, only 30 (3.3%) were to teachers who had completed sufficient coursework to be given a single-subject endorsement in ESS (Table II). Federal guidelines define highly qualified teachers as having an undergraduate major in the content area that they teach. However, the interpretation of what is required content in that major varies from state to state. In other words, one should not automatically assume that an undergraduate degree in secondary ESS education includes a major in the geosciences as it might be the case that the secondary science teacher who has a major in secondary science education has taken a broad range of science courses at the introductory and intermediate levels of science content (i.e., mainly lower-level courses 100, 200, and some 300 levels, but rarely 400 level, or senior-level courses that a undergraduate science major would enroll in). For example, at the secondary level (grades 7–12) in Nebraska a single-subject endorsement requires a minimum of 24 credit hours in one of four core science areas (biology, chemistry, physics, or ESS) and a minimum of 12 ancillary credit hours total among the other three core areas (i.e., one course per area; Nebraska Department of Education, 2016).

We also asked teachers who participated in Phase I of our study to describe the kinds of professional development activities that were available to them within and outside of their school district to strengthen their ESS content knowledge after completing their initial certification. The majority of teachers (87.5%) stated that they needed to go beyond their district to seek teacher professional development specifically in ESS. These avenues included enrolling in online courses in ESS, attending teacher professional development provided through grant-funded projects, and attending specific workshops or sessions at conferences sponsored by state and national science teacher professional organizations. Only the largest school districts were able to provide science-specific professional development, but even that was not offered on a consistent basis and teachers often sought professional development from other venues.

Alternate Route to Teaching ESS

Many Nebraska teachers also seek what is referred to as a "broad field" or "general science" endorsement that allows a science teacher to teach any area of science. For a general science endorsement, until the academic year 2012–2013, the state required 24 credit hours in one area (e.g., biology) and then another eight credit hours in each of the other three areas, which was another 24 credit hours, for a total of 48 credit hours among all four areas of science to teach any secondary level science course. In 2012 the state changed the minimum requirement to 12 credit hours each in all four disciplines for the broad field science endorsement, maintaining the minimum of 48 credit hours in total by removing any one area of expertise rather than increase the requirement for the general science endorsement to 60 credit hours by expecting more depth in one area. Usually an undergraduate science minor requires at least 18 credit hours

TABLE II. Number of Nebraska science teacher endorsements (initial or added) awarded by year.

Endorsement	2007–2008[1]	2008–2009[1]	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014	2014–2015
ESS	**5**	**1**	**0**	**0**	**0**	**9**	**9**	**6**
Biology	20	15	20	25	29	47	24	27
Chemistry	5	3	5	8	8	22	18	16
Physics	3	2	2	2	4	10	12	8
Science	NA	NA	NA	NA	NA	55	52	59
Field Middle Level	NA	19	28	30	20	24	18	26
Physical Science[2]	20	8	3	4	5	*Retired*	NA	NA
Natural Science[2]	12	34	26	48	45	*Retired*	NA	NA
Total	65	82	84	117	111	167	133	142

[1] Data reported by Nebraska Department of Education except for 2008–2009 and 2007–2008, which were self-reported by individual colleges or universities.
[2] Retired "broad field" endorsements (natural Science was a certification to teach all four areas of science and physical science was for teachers to teach all areas except biology). The "science" endorsement replaced these two endorsements as a general science endorsement with 12 credit hours required in each of the four subject areas.

and a science major is 36+ credit hours in one subject or field of science. Thus, it is likely that the majority of Nebraska science teachers teaching ESS out-of-field have been doing so with less than a minor in the subject and without the more advanced undergraduate coursework that a major in that area would have completed.

In Phase II of our study, the online survey, 81.3% ($n = 39$) of school administrators reported that at their high school there was no ESS single-subject certified teacher. Seven (14.6%) responded that they employ one ESS single-subject certified teacher and two (4.2%) responded that there were two teachers with an ESS single-subject certification. Additionally, 58.3% of the administrators responded that of the teachers in their high school or secondary school who are assigned to teach ESS hold a broad field science endorsement (likely with only 8–12 ESS credit hours; Table III). This is consistent with the statewide paucity of available science teachers with single-subject endorsements in ESS and a heavy reliance upon the broad field general science endorsement as a way to meet state credentialing without expertise in ESS.

Different Models of High School ESS Education

In our investigation of how Nebraska public school districts decided to deliver grades 9–12 ESS education and in response to our second research question, *How do school districts provide ESS education at the high school level?*, we found some variation of two basic models. ESS, if taught, is either: (a) a stand-alone course required for graduation in a semester or year-long format (only 12% of Phase I sampled districts and 27% in Phase II sampled districts' high schools); or (b) ESS concepts are included with other preexisting high school science classes. The latter model was the one that was most commonly reported as occurring with selected ESS concepts being expected to be taught alongside physical science (38%) or biology (6%) or in both courses (38%). We show the results from Phase I in Fig. 3 and comparatively from both Phase I and II in Fig. 4. The state does not set specific requirements for length or course design in Nebraska schools, but rather allows school districts to determine how the content is delivered.

Sometimes the term "integrated" was used to describe the approach to addressing ESS and physical science standards in a 9th grade course. However, upon further questioning while interviewing high school ESS teachers during Phase I of the study, it became apparent that the ESS science content was not taught in an integrated manner with the physical science topics, but was delivered as separate, sequential units of study. Thus, readers of this report are advised not to assume that the curricular approach that was used in this sample reflected an interwoven, integration of the content, e.g., studying density and isostasy as a property of matter in the context of learning about plate tectonics. The exact nature of these two models is likely to vary greatly by context in how they were designed and enacted by individual schools and teachers.

In addition to our summary of the findings from both phases of research we provide three examples of school districts (made anonymous with pseudonyms) from very large, large, and smallest size classifications to illustrate the common types of supports and challenges to including high school ESS content in students' required science content coursework for graduation. In these examples generated from participants in Phase I of the study, at the time of data collection there were no high school ESS courses being taught by teachers with an ESS single-subject endorsement, thus all examples are of teachers who were assigned to teach ESS through their general or non-ESS science endorsement.

Examples of School Districts' Approaches to Providing ESS Education

In all of the Phase I interviews, we spoke with the science teacher who was responsible for teaching ESS content at the participating district's high school. Sometimes we also spoke to the district curriculum coordinator, but in most cases that person was not as intimately involved with the ESS science curriculum the ways teachers and department chairs were. Also most smaller school districts (Phase I sample = 87.5%, Phase II sample = 81.6%), unlike large school districts, did not have a designated science-only curriculum coordinator who provided additional support to the science teachers for the teaching of science and translating the ESS state standards into course curriculum. Based upon our interviews with teachers and district-level curriculum coordinators across demographic categories, we constructed the following vignettes to illustrate some of the typical supports and challenges that teachers and district-

TABLE III. Comparison of Phase I and II sample demographics and findings.

	Phase I		Phase II	
Variable	Interviews with Districts Summary (*n* = 16)	SD[3]	Online Survey HS/District Summary (*n* = 48)	SD[3]
Number of public high schools in all sampled districts	22		17	
Number of public secondary schools (7–12) in all sampled districts	5		31	
Total number of HS students included in sample	30,819		11,436	
% of all Nebraska HS students	34.91		12.95	
County average household income	$43,792	$5,033	$45,428	$6,941
County poverty % all ages	14.16	3.57	12.81	3.00
% Free and Reduced Lunch (2013–2014)	48.14	12.49	41.80 (*n* = 47)	14.55
2013–2014 NeSA 11th grade ESS subscores (% correct)	64.31	6.24	65.74 (*n* = 43)	7.84
# of 11th grade students tested	7,268		2,809	
District-level science curriculum coordinator	2[1] (12.5%)		9 (18.37%)	
Number of 9–12 science teachers in study districts	271		159[2]	
% of all Nebraska 9–12 science teachers (*n* = 1,046)	25.9		15.2	
Number of single-subject ESS certified HS teachers	4		11	
% of total HS science teachers ESS certified in districts sampled	1.47		6.92	
Districts in which:		%		%
no 9–12 ESS taught	1	6.25	0	0
Stand-alone required ESS course	2	12.50	13	27.08
ESS integrated into physical science only	6	37.50	15	31.25
ESS integrated into biology only	1	6.25	2	4.17
ESS integrated into both physical science and biology	6	37.50	20	41.67
[4]Other (only for online survey results)	NA	NA	10	20.83

[1] These 2 districts serve 26.85% of state's HS students.
[2] No data for one school because it was merged into another school. One high school science teacher from the resulting high school was counted. *n* = 158 if only resultant HS is counted.
[3] SD is offered where applicable and meaningful.
[4] Other: In Phase II of the survey-based study, survey respondents had the option to select other, but without an opportunity to interview these individuals we do not know what other ways ESS is being addressed, although some schools offer ESS as an elective course and some of these "other" approaches may include this option.

level personnel reported in providing ESS education in their high schools.

Urban School District #1 (USD #1)

USD #1 is a large district with seven large high schools. There are a few secondary science teachers with an ESS endorsement in the district, but they all teach at the middle school level; none of the teachers assigned to teach ESS content at the high school level have a single-subject ESS endorsement. These staffing assignments reflected past K–12 programmatic choices in which ESS was covered in 8th grade to free up more time in the high school curriculum for advanced placement (AP) courses and electives. ESS standards are not taught through a stand-alone ESS course, but have been added, since the last revision of the state standards, to the required physical science and biology courses, which are generally taken during the students' 9th and 10th grade years. These classes are large, with 28–30 students. In addition to these two courses, students are required to take a third year of science. Physics used to be required as the third-year science course, but several years ago, USD #1's science graduation requirements were changed in response to the state policy that increased science instruction to three from two years. Now students are allowed to choose an elective for their required third science course. This might be helpful in boosting enrollment in ESS courses, as prior to three years ago, ESS electives did not count toward graduation requirements. In USD #1, there are very few ESS courses offered as electives, and of these, "Earth Science 3–4," is available only to juniors and seniors who have already completed their physical science and biology requirements, and is the most commonly offered course. In addition to "Earth Science 3–4," one of the seven high schools, and the only one with a planetarium, offers an astronomy course, and another high school offers the only ESS-related AP course, AP Environmental Science. Thus, while there are numerous opportunities for more advanced and focused ESS learning experiences, they are not required nor available to all students. The district paid a talented science teacher, who had taken enough ESS coursework to qualify for a single-subject endorsement in ESS, over a few summers to develop curricular resources for teachers throughout the district to use with their students. However, teachers were mostly left on their own to decide how to

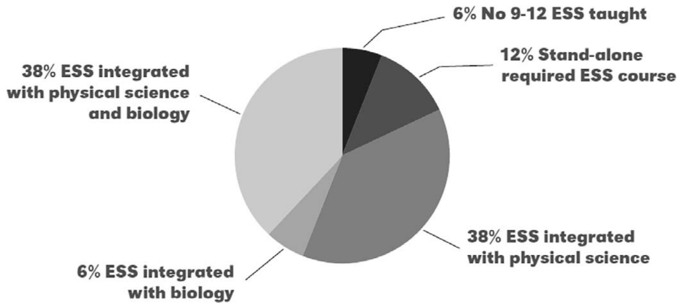


FIGURE 3. Phase I results showing how ESS content was taught at 16 school districts using different course designs.

include ESS content in the 9th and 10th grade required science courses.

Large Suburban School District (LSSD #1)

In LSSD #1 ESS standards are taught in a stand-alone, semester-long ESS course that is required of all students for graduation in the school district. Although in some of its high schools students could potentially take a full year or 1.5 years of ESS courses by taking more specific, upper-level elective astronomy or Earth systems courses, most students only take the standard geoscience and physical science as individual semester-long courses in 9th grade and biology as a year-long course in 10th grade. In this district chemistry is usually taken in the 11th grade and a small percent of college-bound students take either upper-level physics or a life science elective (e.g., anatomy and physiology) as a 12th grade elective. The semester-long geoscience course covers areas included in the state standards such as geology, meteorology, oceanography, and astronomy. In addition to the general level geoscience course, there is also an honors-level geoscience course for higher-performing students. For students with special needs, there is a year-long basic geoscience course taught by mainstream science teachers. For students with more severe or profound special needs, they can enroll in an introduction to geoscience taught by secondary special education teachers who are not required to have any science teaching endorsement. Class sizes are large, ranging from 26–30 students.

There is no common curriculum for geoscience in the district, but all schools have the same objectives and textbooks. The district curriculum resources website has high school geoscience content broken down by topic so that teachers can share what they have used among the six high schools. Class activities are usually paper-based or projected simulations rather than lab-based because of resource limitations. Students may go to the computer room once or twice each semester, but it depends on the school and individual teachers' pedagogical preferences. Since completing our data collection for this study there is now one single-subject ESS certified high school teacher in the district.

Small Rural School District #1 (SRSD #1)

SRSD #1 has only one high school and no district level science-only curriculum coordinator. All students take their science classes with the only science teacher, Mr. James, who is also the science department chair. There are 10–15 students per class and usually there is only one grade level per class. To graduate, students need to take physical science, biology, and a third science class and they can choose from courses such as chemistry or advanced biology. For efficiency, ESS standards are integrated into the physical

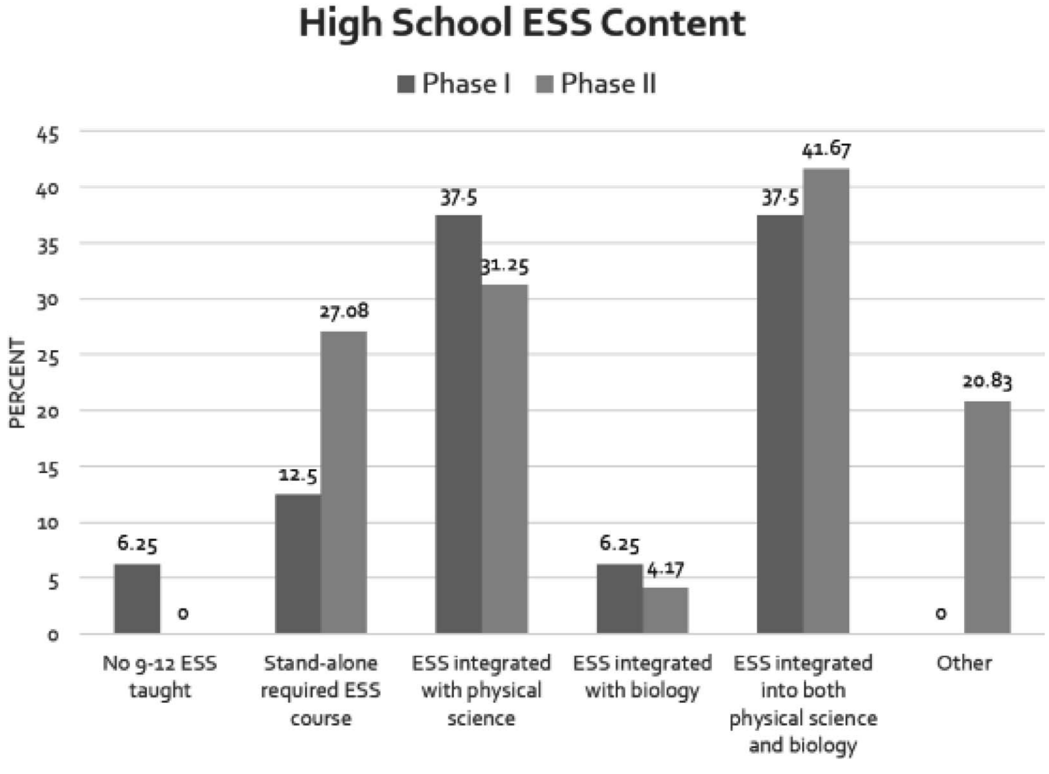


FIGURE 4. Comparison between Phase I and II results of high school ESS content delivery.

science and biology classes. Students rarely go outside for science lessons due to short class periods and the teacher uses lecturing as a common instructional strategy. Mr. James has two single-subject endorsements, one in biology and a second in chemistry. He took meteorology and astronomy in college, but never took any geology classes, and states that he feels least comfortable teaching Earth science topics. He has attended professional development workshops and has been taking graduate level courses to better teach ESS standards because he is committed to providing a strong science education for his students.

ESS Curricular Resources and Commonly-Taught Topics

An ancillary analysis to our research question of how ESS is being taught concerned what kind of access high school students have to ESS content. We were interested in the common characteristics of ESS instruction. Thus, in Phase II of our study there was a series of questions on the survey that asked the participants to identify how ESS was being taught beyond when the content was being offered during the grades 9–12 science program. The following section and Fig. 5 highlights selected results from the survey results. A more complete summary of the survey results can be found in Table C1 in Supplemental Material C (available in the online journal and at http://dx.doi.org/10.5408/17-253s3).

ESS Curriculum Resources

Respondents reported using different ESS textbooks, but no one textbook was reported by more than eight schools (16.7%). This suggests that there is not a strong presence or leadership in the state in terms of ESS textbook review, recommendations, or adoption. Some survey respondents (18.75%) report using online resources, which may also include the use of an online textbook as well as online simulations and websites. More specifically 22.9% of respondents report using 1:1 technology with students such as a laptop or tablet. These are low rates considering the large amount of online resources available from the U.S. Geological Survey, National Oceanic and Atmospheric Administration, NASA, and ESS curricular resources cataloged in the Digital Library for Earth Systems Education (DLESE). Furthermore, only 20.8% report using laboratory materials and only 8.3% report using outdoor field equipment. This suggests that only one in five students enrolled in the surveyed schools have access to a lab-based curriculum. It may be possible that there is a lack of funding that supports authentic, hands-on learning in ESS; however, this would need to be further investigated.

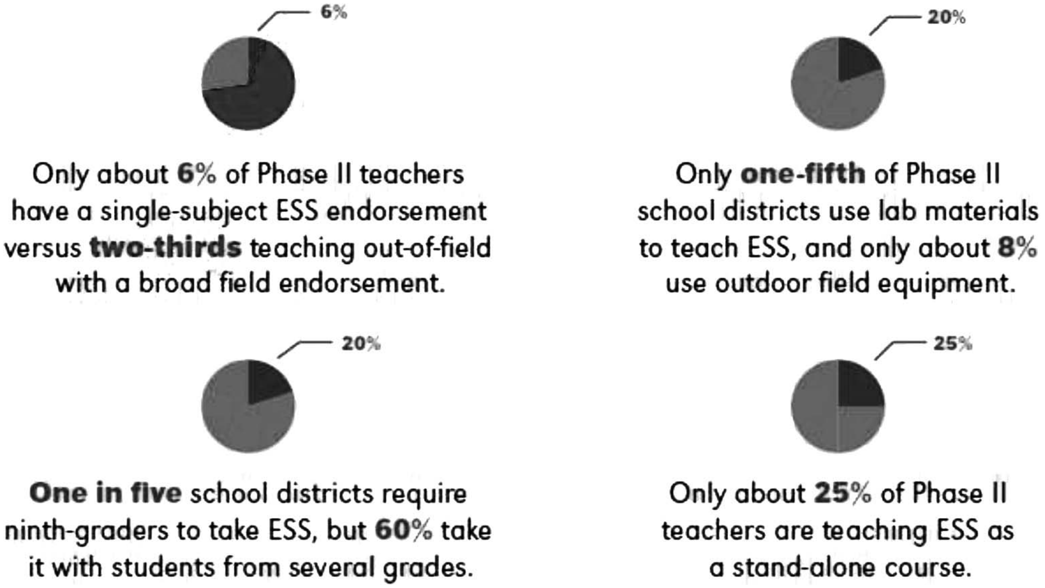
ESS Topics Taught

The most commonly reported ESS topics that were taught in greater than 60% of the surveyed school districts include: (a) the solar system ($n = 32$, 66.7%), (b) climate ($n = 31$, 64.6%) and climate change ($n = 30$, 62.5%); (c) weather and meteorology ($n = 30$, 62.5%); and (d) the rock cycle ($n = 29$, 60.4%). State science standards concerning the solar system are at the middle school level (Nebraska Department of Education, 2010), and it is unclear why high school students are spending time on a lower level topic in their scope and sequence. The topics that were taught in fewer than 60% of school districts included: (a) plate tectonic theory ($n = 28$, 58.3%); (b) fossils ($n = 28$, 58.3%) and geologic time ($n = 27$, 56.3%; (c) stellar evolution ($n = 19$, 39.6%); and (d) physical oceanography ($n = 9$, 18.8%). We do not know why particular topics are more popular than others, although we speculate that it is easier to add some topics to biology (e.g., climate) and physical science (e.g., radioactive decay and absolute age dating) courses than others. It is discouraging to see that plate tectonics, the unifying theory of geology, was not a common topic in all surveyed schools. Stellar evolution has natural connections to the electromagnetic spectrum, a strong physical science connection, but was only reported as being taught in about 40% of schools. And physical oceanography, which is a traditional part of Earth Science curricula as a vital component of the hydrosphere in Earth systems science, appears to be accessible to only one in five students at these schools. Nebraska is not a coastal state and it is possible that teachers may have been discounting students' interest in oceans because their students may have never personally seen an ocean.

Students' ESS Performance on State High School Science Test

As a final point of interest we investigated students' performance on the ESS items on the state's high school multiple-choice science test, which addressed our third and final research question, *How do high school students perform on the ESS portion of the state science test?* Because the presence of state level tests can drive students' access to science education at their schools we were curious as to students' performance on the Nebraska 11th grade test. The design of the 11th grade science test is approximately 25% in each domain of science (Earth and space science, life science, and physical science) for a total of 75% and the remaining 25% of items focus on inquiry and scientific practices. In reviewing the 11th grade practice science test provided in 2012 and the test specifications it was clear that most ESS content questions required only basic recall (e.g., *1. Which object is the smallest: galaxy, universe, planet, or star? 2. What is the source of energy that moves tectonic plates?*) and there was one example question that required application of knowledge (e.g., *1. A fossil contains 12.5% of the original amount of a radioactive isotope. The half-life of the isotope is 8,000 years. About how old is the fossil?*). Respectively, these assessment items reflect depth of knowledge (DOK) questions in Category 1 (i.e., recall of facts) and Category 2 (i.e., using a skill or applying a concept; Hess et al., 2009). Without seeing the actual test and its items we do not know how well the entire test aligns to the state standards.

We used the data that was available to us and initially searched the state department of education's website for the 2013–2014 academic year test scores by school district. We also disaggregated the state data by race and students who qualified for a free or reduced lunch (FRL) program. The state average ESS subscore was 64.20% (SD = 4.83) for all 11th grade students. At the state level students who qualified for FRL scored on average 9% lower and Black or African American students scored 17% lower than the average (Table I). Both Phase I ($M = 64.31\%$, SD = 6.24) and Phase II ($M = 65.74\%$, SD = 7.84) district samples yielded a similar average score and SD on the ESS portion of the high school science test (Tables I and III). However, the full range of student performance on the state ESS test questions among



Only about **6%** of Phase II teachers have a single-subject ESS endorsement versus **two-thirds** teaching out-of-field with a broad field endorsement.

Only **one-fifth** of Phase II school districts use lab materials to teach ESS, and only about **8%** use outdoor field equipment.

One in five school districts require ninth-graders to take ESS, but **60%** take it with students from several grades.

Only about **25%** of Phase II teachers are teaching ESS as a stand-alone course.

FIGURE 5. Selected results from Phase II survey on (clockwise from top left): teachers' endorsement, school district use of lab and field-based equipment to teach ESS, when students take ESS, and availability of ESS as a stand-alone course.

all sampled school districts ranged from 33% to 79%. Because the majority of sampled districts only had one high school, their scores can also be considered representative of their district-level performance.

We conducted a further analysis of the 16 Phase I school districts and compiled a 5-y average of ESS, life science, and physical science subscores from the state's 11th grade science test (Table IV). Due to the protected status of one school as it had a very low student enrollment in a rural area, we had to remove it from the dataset as no data was made publically available for four of the five years. The majority of these schools (87%, $n = 15$) did not employ a science teacher with an ESS endorsement who taught an ESS course, rendering it improper to compare test scores from schools with in-field ESS teachers with out-of-field teachers. Upon inspection of the state science subscores, in every case except two school districts in the Phase I study sample, life science was the highest subscore. In these two school districts that had ESS as a higher score, one school offered ESS as an 11th grade elective that the interviewed teacher reported 75% of their students took as part of their graduation requirements in science. The second school with a higher ESS subscore also offered ESS as an elective course for junior and seniors, but we do not know what percent of the students took the course as it was not known at the time that we interviewed the teacher from that school district. However, in both of these cases the state test was taken right after the course was taken so the ESS content was probably fresher in the students' minds.

Finally, to investigate the relation between socioeconomic status and student performance we graphed the relationship between the sample of Phase I ($n = 15$) school district's high school state ESS subscores and the percentage of students who qualify for free or reduced lunch (Fig. 6). This resulted in an inverse relationship as poverty rates increased, average ESS test scores decreased ($y = -0.0033x + 0.8058$, $R^2 = 0.7846$). We discuss the relationship between poverty rates and academic performance in the discussion section.

Discussion and Implications

In summary, the majority of the modes in which ESS content was delivered was by a non-ESS teacher in the 9th grade alongside the physical science curriculum. There were only a few instances in which ESS was a stand-alone course, either as described previously when it was offered an upper-level elective, or two instances in which it was a 9th grade stand-alone course.

State and sample district test scores indicated that life science was nearly always the highest scoring part of the state science test, followed by ESS and physical science (Table IV). However, while the three subscores do not differ greatly from each other and hover around the 66% mark, the differences among them are real as the sample of students tested is a population sample (i.e., all 11th grade students in these Nebraska schools took the test). Readers will note that the physical science subscores are not much different from the ESS. Physical science at the high school level assumes that students are taking both chemistry and physics as 11th and 12th grades to deepen their knowledge of conceptual level physical science content that is taken in middle school or 9th grade. We suspect that the physical science test score is as low as the ESS test score because students' access to upper-level physics has similar problems as ESS. A high school physics course is usually treated as a high school science elective, rather than a required course. Students typically take high school physics as 12th graders, which would be after they take the state high school science test as 11th graders. There are also likely to be as many out-of-field chemistry and physics teachers (Table II) as there are out-of-field ESS teachers.

Additionally, it may be that in comparing ESS with life and physical science administrators and teachers do not view the low ESS scores as a major problem in and of themselves, but are more concerned with the overall science scores from

TABLE IV. 5-y average of district performance on state science tests scores in ESS, life science, physical science, and inquiry.

	ESS (%)	Life Science (%)	Physical Science (%)	Inquiry (%)
State 5-y Average	64.20	67.40	62.60	66.40
Phase I School District Sample Average ($n = 15$)	64.58	67.17	62.30	67.13
Phase I SD	4.83	5.45	4.64	6.16

year to year. Unfortunately, without disaggregating ESS from the other sciences, district and school-level administrators' curricular and policy decisions may inadvertently perpetuate the marginalized status of ESS. One could also argue that the scores are a low level of success for science in general and for ESS specifically that can be attributed to the majority of Nebraska science teachers holding a general science endorsement as opposed to single-subject endorsements at the high school level.

Another variable that may contribute to these low state test scores is socioeconomic status. Nationally speaking, American youth score very high in math and science, better than students in the highest ranked countries (e.g., Finland, Japan), if they are in schools where only 0–10% of the children are poor; and students still perform well if between 10% and 24.9% of children are living in poverty (Berliner, 2013). However, as poverty rates increase beyond 50%, academic performance is below those children of higher SES in the U.S. As reported by the National Center for Children in Poverty (2016) about 15 million children in the United States live in families with incomes below the federal poverty threshold, a measurement that has been shown to underestimate the needs of families. Considering that about 45% of Nebraska students qualify for their free or reduced lunch program it is likely that this level of poverty may be having a depressive effect on state science test scores despite efforts to improve science curriculum coordination and overall school improvement.

We would stress that the presence of persistent poverty does not negate the importance of improving teacher qualifications and classroom instruction as those factors can lead to better access and opportunities for all students to learn ESS. Although directly observing teachers' classroom instruction and correlating effective teaching with teacher qualifications was beyond the scope of our study, other researchers have investigated this connection in life science, but not ESS education. In a meta-analysis of 65 studies, Druva and Anderson (1983) found that student science achievement was positively related to their biology teachers' number of biology courses and overall number of science courses (National Research Council, 2007).

Challenges to High School ESS Education

The study's findings and our three example school districts represent a range of challenges and approaches that urban, suburban, and rural Nebraska high schools and districts face in order to meet state and national ESS standards. Here, we discuss the implications of ESS curriculum choices and ESS teaching by underqualified ESS teachers.

Most often out-of-field science teachers have been assigned to teach ESS. Generally, in larger districts there are more resources available through the district and curriculum specialists devoted to supporting science teachers, especially when they are teaching outside of their main endorsements. In small rural schools, where there may only be one science teacher at a single high school, science teachers are especially challenged to teach all areas of science equally well (Ingersoll and Perda, 2009). On the whole, in our study we found that the science teachers we interviewed noted that it takes time, effort, and money to seek out professional development in ESS because it is not offered by their school districts and many Nebraska school districts are too small to have a science-specific curriculum coordinator to assist them. Given time a motivated veteran, rural science teacher is more likely to have learned how to teach all subject areas than a new science teacher with only an initial teaching endorsement (Oliver, 2007). However, regardless of experience, teachers in rural areas still experience pressure to teach all subjects equally well and the workload demands to prepare and teach multiple subjects has been linked to teacher career dissatisfaction (Goodpaster et al., 2012). Recruitment of science teachers is difficult and new teachers often do not remain in these positions for very long unless they have strong ties to the community (Oliver, 2007). This mirrors findings reported by Ingersoll and Merrill (2010) in which they report that teacher turnover differs across states, regions, and school districts. The data that they used generated from the Schools and Staffing Survey (SASS) and its supplement, the Teacher Follow-Up Survey (TFS) generated in the 2004–2005 academic year that 45% of all public school teacher turnover happened in 25% of all public schools. "High-poverty, high-minority, urban, and rural schools have the highest rates of turnover…The data show a significant annual shuffling of teachers from poor to wealthier schools, from high-minority to low-minority schools, and from urban to suburban schools" (Ingersoll and Merrill, 2010, 19). Regardless of location, unless a new science teacher is

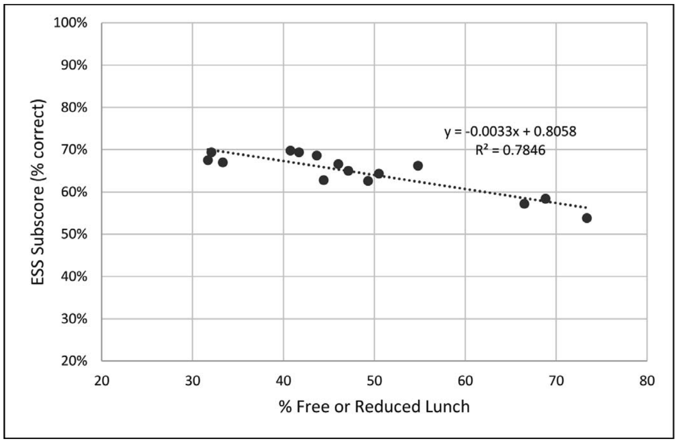


FIGURE 6. Relationship between the Phase I ($n = 15$) school districts' 11th grade state ESS subscore and the percentage of those students who qualify for free or reduced lunch.

already endorsed in ESS, automatically he or she will be teaching ESS out-of-field in addition to being an inexperienced teacher.

Self-efficacious teachers are typically more willing and motivated to incorporate newer constructivist approaches (i.e., inquiry) to teach science (Jones and Carter, 2007). Conversely, when teachers teach out-of-field they lack the confidence and ESS subject matter knowledge to teach using inquiry-based approaches and are less likely to recognize their students' misconceptions and oversimplifications present in science textbooks, Web sites, or other readily-available materials. With the vast majority of Nebraska science teachers teaching ESS without a single-subject endorsement in ESS, it is likely that ESS instruction is of lesser quality than another content area, such as biology in which teachers hold a single-subject endorsement. Teachers who lack subject matter knowledge also tend to teach more didactically than in-field teachers (Jones and Carter, 2007). Students who lack high-quality opportunities to learn ESS will not be successful on small- and large-scale assessments.

Although Nebraska is not an adopter of the NGSS, other states with similar state-level science teacher endorsement policies and practices will be similarly disadvantaged by assigning out-of-field science teachers to teach ESS. States similar to Nebraska with large numbers of rural schools may also be experiencing similar teacher staffing challenges. Ultimately, rigorous state- and national-level testing aligned with the NGSS needs to be supported by students' opportunities to learn ESS from highly-qualified science teachers in this domain of science.

Policy Implications

District Level

As shown in our interview and survey data, from a systemic design and staffing standpoint school districts control the course structure of how ESS state and national standards are implemented in high school classrooms. With Nebraska's testing of ESS as part of the state high school science test in the 11th grade, school administrators are faced with difficult decisions when making hiring and ongoing staffing decisions about who is qualified to teach ESS. Although it is a positive action that administrators and teachers have been more motivated to include more ESS content, conversely, many more out-of-field science teachers have been recruited to teach this ESS content. In this sense, rural schools without district science curriculum coordinators may be at a particular disadvantage in that solo or a small group of science teachers are without in-house systemic support, especially when they are teaching ESS out-of-field. And adding ESS curriculum to an already-full science domain may have an adverse effect on students' learning of both domains. For example, adding ESS content to a biology course as parallel, rather than integrated, curriculum may give short shrift to the ESS domain by forcing teachers to revert to didactic means to cover topics quickly, but functionally also takes away time spent developing students' conceptual development in the life science domain.

State Level

State-level teacher endorsement policies may inadvertently support out-of-field teaching of ESS; i.e., providing a route for a general science endorsement with minimal subject matter requirements and little depth of knowledge. Given that state testing may have positively encouraged the inclusion of ESS content in the 9–12 curriculum by school districts, such assessment policies may also generate a systemic need for teacher professional development in ESS content. Our data reveal that currently such professional development opportunities mainly exist in grant-funded programs or higher-education coursework that are limited in how many teachers can attend, are expensive on a teaching salary, and are purely voluntary. A report by the Council of Chief State School Officers (2012) stated that, "our current licensure systems are antiquated and have lost credibility with the public. They should be revised to ensure they align with new performance expectations and realities" (CCSSO, 2012, 16). Many states have dispensed with their general science endorsement, but may only require that teachers pass a content test to teach science. Teachers assigned to teach ESS should be highly qualified and state licensure policies should act as a gatekeeper to prevent impoverished science education.

NGSS ESS Standards and Adoption

As of this writing there is no comparable stand-alone model for an ESS course in the NGSS ancillary materials, as there is with biology, chemistry, and physics. This appears to reflect the status quo of ad hoc ESS education efforts at the high school level rather than providing a modern vision of science education in which the century-old 9th grade physical science course is replaced with critically needed ESS education. Although dividing ESS topics that connect to other domains of science may be helpful in assisting students to make natural connections among the sciences, it undermines an Earth systems-based curricular cohesiveness that could encourage student learning and construction of strong conceptual frameworks in ESS.

To date, Nebraska has not adopted the NGSS. However, when we interviewed the state science specialist it was clear that in the last revision of the state standards that occurred two years prior to the release of the NGSS frameworks in 2010, there was an effort made to ensure that there was clear alignment with the science education frameworks for the new national standards. There is at least one Nebraska school district in our study that decided to adopt the NGSS on its own to guide K–12 science education programs in its schools. The state science standards are currently being revised (2016–2017 academic year) using the NGSS Frameworks so that students will be expected to meet similar performance expectations.

Limitations of Study and Recommendations for Future Studies

A limitation of our study is that this was a case study of one specific state, although we note that other states are operating under similar conditions and could benefit by comparing their own state science teacher certification policies with those of Nebraska to see how policy plays out in practice at district and high school levels. Although the survey results from Phase II of our study gave us a snapshot of what specific ESS topics are being commonly taught, 22.9% of school representatives did not respond to that particular question. This may be because we asked school principals to respond to the survey rather than the teacher assigned to teach the ESS content. Another limitation is that we did not observe ESS instruction in schools firsthand, but relied upon teachers' general description of how ESS was being delivered in the classroom. We also did not study the gain scores of students enrolled in various 9–12 science programs in which ESS was taught alone or with another science.

Thus, one direction for future research in this policy arena is to replicate the study with a similar methodology in another state that has adopted NGSS. Because Nebraska is a state that has plans to adapt the NGSS and not adopt them wholesale and we found that state-level teacher certification policies appear to have inadvertently supported out-of-field teaching of ESS, it would be useful to investigate an NGSS-adopting state to find out if NGSS adoption policy has affected teacher credentialing practices, or if teacher certification policies have facilitated the adoption of NGSS. Another research focus would be to investigate the teaching practices of in- and out-of-field ESS teachers and how greater subject matter knowledge relates to students' academic achievement. For example, how in- and out-of-field ESS teachers structure and enact units of study would provide useful information for teacher educators in designing teacher preparation and professional development programs as well as inform state-level teaching endorsement policies as to how much content knowledge is enough to teach ESS effectively.

Two other avenues of productive research concern assessment of student learning of ESS content and encouraging more high school students to pursue undergraduate degrees in the geosciences. The first would require gaining access to state test score databases to be able to correlate such factors as district SES, ESS teacher credentials, and student performance. The second requires developing a mechanism for tracking high school to college level matriculation rates. In summary, future studies should focus on extending our work by: (a) building models of the full educational system from policy to practice (i.e., state-to-district-to-school levels); (b) recruit in- and out-of-field ESS teachers to help determine minimum levels of subject matter knowledge that reliably result in effective ESS instruction; (c) generate cases of in- and out-of-field ESS teaching; and (d) student learning gains through different models of ESS delivery (e.g., domain-specific or "bundled").

Conclusion: The Future of High School Earth and Space Science Education

In secondary ESS education the stakes are uncomfortably high for continued business-as-usual policy practices if there is continued marginalization of 9–12 ESS education through state-level policy and district-level decisions and classroom practices. Without expertise in ESS, teachers who teach ESS at the high school level are likely to fail in producing strong ESS literacy among their students. Without strong ESS literacy we may never achieve our national vision of scientific literacy as outlined by the AAAS, NRC, NSF, and other science and science education organizations. Impoverished geoscience literacy among American citizens ensures a lack of understanding of environmental issues, disaster preparedness, and prudent resource use (Mayer, 2002). This is problematic when countries and regions all over the world are desperately trying to address societal issues such as climate change, natural disasters, resource management, and environmental degradation.

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