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High school earth and space science should be taught by geoscientists

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By Elizabeth B. Lewis

A recent survey of U.S. science teachers' understanding, perspectives and teaching of climate change — an important earth and space science (ESS) standard included in the new Next Generation Science Standards (NGSS) — revealed that teachers spend an average of only one to

two hours per year teaching students about climate change. The survey study's authors concluded that "[science] teachers may not be very knowledgeable about a wide range of evidence and how climate models work." However, the authors did not distinguish between qualified ESS teachers and other teachers, like biology, physics or chemistry teachers who might be charged with teaching ESS topics. Other studies also noted that some teachers with biology degrees self-report not feeling prepared to teach climate change.

These, and other similar results, suggest that many secondary teachers currently teaching climate change do not have sufficient content knowledge to teach the topic accurately, although they do not explain why teachers are teaching ESS out-of-field, or how we might improve the situation. Without a grounded understanding of how educational systems function, we cannot advance practical solutions to improve science education.

Roadblocks: ESS Education Marginalization and Lack of Expertise

Because of its multifaceted nature, teaching ESS takes expertise and time. Secondary science teachers tend to have particular expertise in one of three domains — life sciences, physical sciences or ESS — each of which has its own theories, concepts and disciplinary core ideas. Effective ESS teaching requires that teachers adopt a systemic approach to build students' knowledge of all Earth systems (geosphere/hydrosphere/atmosphere), ideally, in well-developed curricular units ranging from four to six weeks in length. However, this teaching model has not been adopted consistently. Content knowledge matters in successful teaching. It may seem to be common sense to assume that ESS is taught by qualified teachers, but, unfortunately, this is not the case in every state, even though 42 states require secondary teachers to take science content tests in the subjects they teach for licensure.

In high school ESS education, there is a history of marginalization nationally that reveals a desperate shortage of qualified ESS teachers to teach issues critical to society. And geoscience education scholars have reported minimal success of, and sometimes political resistance to, ESS education in the last 40 years. Many factors are involved, but some have been more difficult to overcome than others, including perceptions of geoscience as a lesser science, stalled attempts to include ESS in high school curricula, and insufficient numbers of qualified ESS teachers.

First, geology has long held a low status compared to the "Nobel" sciences, in part due to a misperceived lack of mathematical rigor. Second, earth science was not considered a viable subject on its own until the 1960s with the advent of plate tectonic theory. Unfortunately, the movement to include ESS in high school science curricula in the 1960s and 1970s was not as successful as proponents hoped, despite millions of dollars of National Science Foundation funding for ESS curriculum development and teacher professional development.

The language of the new NGSS explicitly mentions climate change, and ESS has been identified as an equal domain of science (alongside the life and physical sciences) since the introduction of the first national science education standards in 1996. But ultimately, it is states, school districts and administrators who control students' access to ESS as a course of study, and after 20 years, ESS largely remains on the sidelines in high school science education. The National Association

of Geoscience Teachers (NAGT) reports that 8th grade is often the last time American students study ESS. High school students' access to the subject in classes varies widely from state to state, but, on average, just 11 percent take an ESS course. (New York is an exception, with more than 70 percent of high school students studying ESS to meet graduation requirements.) With numbers like these, we should not be surprised that the public struggles to understand human-induced global warming.

Finally, there have never been enough highly qualified ESS teachers. In 1966, it was estimated that there were about 6,000 to 7,000 earth science teachers in the U.S., but the Earth Science Curriculum Project staff predicted a need for 20,000 teachers by 1970. Fifty years later, the number of ESS teachers (15,611) still falls far short of the number of biology teachers (52,697), who teach the 88 percent of all high school students nationwide who take one biology course. If ESS is to be taught at the same frequency and quality as biology courses, many more competent ESS teachers must be prepared and hired.

Furthermore, tallies of what courses are offered and taught alone do not reveal how many teachers are teaching ESS in- or out-of-field. To know how many teachers hold rigorous ESS licenses, we must inspect each state's requirements and records. For example, in a recent study of Nebraska, my colleague and I found that only 31 new ESS certifications were approved from 2008 to 2016, meaning only 2.9 percent of the more than 1,000 new science teachers certified in that period earned an ESS endorsement with a minimum of 24 credit-hours of ESS college-level coursework.

In states where all high school students are to be tested in ESS, administrators must ensure there are opportunities for students to learn ESS, even if it means having science teachers teaching out-of-field. In our case study of Nebraska, the most common approach, adopted by nearly 75 percent of the surveyed school districts, was to include ESS standards in preexisting 9th-grade physical science and/or 10th-grade biology courses. Unfortunately, this does not necessarily mean that those teachers assigned to teach ESS are highly qualified to do so. State policies requiring rigorous science teaching credentials would help ensure there will be a supply of highly qualified ESS teachers to hire.

Robust High School Education and Teacher Preparation

Decades ago, geoscience advocates proposed that professional development opportunities in ESS could be provided to science teachers already certified in other areas, but this did not rectify the insufficient numbers of qualified ESS teachers. Optional professional development is insufficiently systematic to result in widespread improvements in ESS education. Such workshops do not reach all teachers in need, nor do they address how many school systems have marginalized ESS or that some states do not require teacher certification in ESS. While all teachers can take it upon themselves to learn more about climate change, retrofitting knowledge takes time, effort and money. Non-ESS teachers cannot realistically be expected to teach complex ESS concepts in comprehensive ways as effectively as well-prepared ESS teachers can in year-long, stand-alone courses.

It is critical to maintain ESS education in science education standards, and how topics like climate change are taught — and by whom — matters. Recently, NAGT issued a position statement on their website calling for "robust earth science education in high school and rigorous training of earth science K–12 teachers." Some states have met the call. For example, New York requires all teachers certified to teach ESS to have at least 30 hours of ESS coursework and another 30 hours of general science. However, some states only require a few college courses in ESS as part of a broader general science endorsement to be certified to teach any science.

Additionally, science teachers with a deep understanding of a particular subject are typically more willing and motivated to encourage students to learn by actively constructing their own understanding and knowledge of the world through experiences rather than passively receiving information. Such approaches better reflect the nature of the scientific method and how scientific understanding of the world is accrued. Unless more states require that ESS be taught by qualified teachers, the current situation of low ESS literacy is unlikely to change.

It is not surprising that all science teachers do not understand climate change or how to teach it; this shouldn't necessarily be an expectation, as we need teachers with expertise across many fields. But, in general, out-of-field teachers are simply not as effective at teaching what they do not know themselves. By requiring initial ESS teacher certification to be more rigorous and content-specific, we can improve secondary ESS education through policy and practice. Better teacher preparation will also help us achieve scientific literacy nationwide and facilitate citizens' understanding of long-term environmental sustainability, global climate change and natural disasters. Ultimately, for future generations to understand the complex planet they live on, we will need more geoscientists to serve as qualified ESS teachers and advocates for ESS education.

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