Beyond the Compass

Redefining Field Education in Geoscience

GSA President Nathan A. Niemi

At GSA Connects 2025, GSA highlighted themes of transition, dissolving borders, and reaching for the stars—mirroring the shifting landscape of geoscience field education. Changing student interests, rapid technology, and ongoing barriers are reshaping what field training must become. Inspiring the next generation to tackle society's geoscience challenges has never been more urgent.

I would like to thank all of you for attending the Presidential Awards Ceremony, to recognize and honor our members for their scientific and community accomplishments. I would like to thank the GSAF, and their leaders, including new ED Sean O'Brien, for their support, as well as incoming GSA President Glenn Thackray, treasurer Brian Katz, and the rest of the GSA Council. And I would like to please give an ovation to Chuck Bailey, who has been a tremendous support to me this year, and who is stepping up for a 4th year of service to GSA.

As Melanie said earlier, we are incredibly excited to be here in San Antonio for the 2025 GSA Connects meeting. This meeting will be the largest since the COVID pandemic, with a rich and diverse array of scientific sessions, invited lectures, field trips, short courses, and social activities. We are pleased at the success of this meeting, which is due to the commitment of the Annual Program Committee, local planning committee, GSA staff, GSA volunteers, and GSA members, such as yourselves, who have chosen to invest your time and resources here in San Antonio.

That being said, it needs to be acknowledged that it has been, at times, a tumultuous path to get here—a challenging year for many in this room, personally, and a difficult year for science in general, as underscored by the absence of many of our colleagues who work for the federal government at the USGS, NOAA, NASA, DOE, or other agencies, as earth scientists.

The topic of my Presidential Address—one of the things that I'm most passionate about, and which gets me out of bed, even on difficult days—is teaching geology in the field. I am a field geologist by training, and research grounded in field-based study typifies the work I continue to do with my graduate students.

I have been fortunate to teach field geology courses for nearly 25 years, and to direct the University of Michigan's Earth and Environmental Science field station for the last 12 years. My connection to field geology is intricately connected to GSA. GSA Graduate Research Grants supported my PhD research, as well as that of my students, and I have been fortunate to teach field geology from two past GSA Presidents: Clark Burchfiel and John Geissman.

Over the past few years, I have spent a lot of time thinking about the future of field camps, field courses, and field trips in the geological sciences, as the landscape around field

geology courses, which was slowly evolving, has begun to more rapidly shift. These shifts have a variety of causes.

Cost is certainly one factor—both the cost to an institution of offering field or place-based learning (as I am constantly reminded by our Dean), and the cost to students of taking field courses, especially if the payment of summer tuition or the loss of a summer job is involved.

Additionally, many faculty trained as field geologists were hired in the wake of the acceptance of plate tectonics, and during the heyday of oil and gas exploration. As these faculty retire, departments are moving in new and different research directions, often eliminating the courses thought of as preparatory for field geology courses, as well as the field geology courses themselves. And, as new faculty are hired, with different research interests and changing expectations in academia, the impetus, or incentives, to develop a multi-week course taught during summer are usually not especially attractive.

Field geology courses are already being eliminated due to declining enrollment and costs, or replaced with shorter field trips, locally based, and taught during traditional academic terms.

What might the future of field education look like for the next generation of students?

To answer that question, it seems reasonable to ask why field geology is taught at all. The answer to that question may be more obvious to those of us who live on boundless expanses of glacial till that are covered by snow five months of the year than to others, and so for many schools, field trips or field camps are an opportunity to see geology in ways that simply isn't possible from local or even regional excursions.

From a curricular perspective, I suspect that many field geology instructors would point to a set of skills (e.g., using a Brunton compass, measuring a stratigraphic section, making a geologic map), and the intention to develop a deeper level of thought processes in students, including:

- thinking in both space and time—a uniquely geologic way to think;
- making a plan to collect data to test a hypothesis;
- drawing an inference from incomplete data; and
- defending that inference, accounting for incompleteness and uncertainty.

A growing body of geoscience education research into field courses and field experiences supports the importance of developing these critical skills through field work.

In addition, for many students, field camps and extended field excursions can be opportunities for personal growth through travel and experiential learning in a new environment. Some students thrive with the ability to focus on one subject, or to get away from distractions at home, or whose strengths are in synthesis and conceptual thinking.

The COVID pandemic in 2020 was a remarkable stimulus in thinking about different ways to achieve field camp teaching objectives. Overnight, every field camp and field course in the country was cancelled, and every institution pivoted to teaching an alternative version of field camp online. To do this effectively, it was critical to start with the key learning outcomes of field camp, and then to ask how those outcomes could be achieved through virtual exercises. An NSF RAPID grant, led by and involving multiple GSA members, convened virtual workshops of field camp instructors across the country to assess the critical learning outcomes of field camps, and then to design and distribute exercises that could be used by any field camp instructor in their virtual field courses.

If you look at some of the key learning outcomes in this framework, it's obvious why teaching a student to make a geologic map, or measure a geologic section, while using pen and paper and traditional data collection methods is effective—these exercises teach many of the crucial skills identified as important learning outcomes of field camp.

Having identified these key learning outcomes opens up horizons beyond developing virtual field exercises based on traditional field camp approaches. This framework provides an opportunity to think about new approaches to teaching in the field, and the possibilities of incorporating different technologies, topics, and themes into field courses.

Traditional field tools remain unquestionably useful for developing quantitative thinking skills and reinforcing student learning by connecting thinking to doing. However, many students (reasonably) don't see use of traditional geologic tools as marketable skills. Students are aware of the importance of geospatial skills in the job market. We are aware that fewer and fewer of the students we graduate will end up with jobs titles "geologist."

We are fortunate that the barriers to using technology in the field have rapidly dissolved. The revolution in computing power over the past two decades has been astonishing. Attempts to use computers in the field 15 or 20 years ago were met with the complaint that students couldn't get up the hill carrying 5 lbs of water and 20 lbs of batteries (they weren't really wrong). Students now carry infinitely more powerful computers in their pockets all the time (well, in their pockets some of the time....)—computers that have batteries that last all day, screens that you can read in direct sunlight, and have Global Positioning System data accurate enough for the teaching of field geology. They are also inexpensive enough to almost completely be ubiquitous.

The revolution in computing has been followed by a revolution in software and app development. This revolution has spearheaded a transition from the use of complex, expensive proprietary software systems that were cumbersome and challenging for students to learning to an ecosystem of lighter-weight, specialized apps aimed specifically at geologic field work and programmed and designed by geologists. The apps work together to accomplish many field geology-oriented tasks, and are easy and intuitive for students to learn and navigate.

Among these I will highlight some developed by GSA members, including StraboSpot, developed by Basil Tikoff and Doug Walker, which is designed for the nested collection of geological data at scales, from geologic mapping, to outcrop description, to thin section analysis. This app is easily modified to simplify its use for field teaching, and students pick up its use quickly.

StraboSpot interacts with apps built by other developers, such as GSA member Rick Allmendinger. One of these is a digital compass app that collects orientation data and allows users to analyze that data on a stereonet in real time while in the field. Rick's own geologic mapping program for field use, Geologic Map Data Explorer, has unique features, including the ability to calculate three-point problems and project geologic contacts, transitioning the app from a tool in which to collect geologic observations and data to one that helps to generate hypotheses that students can test through further field observation. Through such technologies, we can enhance the learning of fundamental field skills that are critical to a practicing geologist, while also teaching computational and geospatial skills that are transferable to other job markets and sectors.

The expense of teaching with technology, including the planned obsolescence of equipment, computers, and software, is one of the biggest impediments to any single institution or entity incorporating technology into field teaching. While the sharing of expensive field-based research equipment has been a long-established practice (e.g., IRIS for seismometers, or UNAVCO for GPS equipment), the practice of pooling and sharing technological equipment for field teaching has had a later genesis.

If not the pioneers of this practice, EarthScope was involved relatively early in the idea of sharing research-grade geodetic equipment with field camps, including GPS and LIDAR (laser scanners). This practice continues, and has expanded, with a suite of geodetic and geophysical equipment available for loan to field education programs. Many earlier adopters of these programs have contributed curriculum, best practices, and instructional ideas to shared teaching resource centers, such as SERC (Science Education and Research Center), Teach the Earth, or GETSI, lowering the barrier to adopting these new technologies. New equipment availability opens the doors to field-based coursework in geodesy, geomorphology, natural hazards, and environmental geology, expanding the range of adoptable field study topics to encompass a greater breadth of student interests, as the need for a new and expanded conception of the topics that can be taught at field camps is crucial.

Student interest in environmental topics, particularly related to the habitability of our planet—from climate change, to water quality, to wild fire and natural hazards—has increased markedly over the past several years. In my own department, the number of students interested in pursuing environmentally oriented degrees outpace those interested in a more traditional earth science degree by a factor of two. This shift in student interests presents a challenge and an opportunity.

The challenge is that differentiating field studies as a component of "only" the "traditional" path through the earth sciences, and not as an integral part of an "envirionmental" path through a degree program, will inevitably lead to diminishing participation in field camps or field studies. It will also minimize the opportunity to train all of our students in some of the fundamental aspects of understanding earth science, whether over millions of years, or over the past millennia.

The opportunity presented to us is to incorporate environmental science as inherently linked to geology, and vice versa. This is perhaps more easily said than done, and I am fortunate to be teaching in a department of earth and environmental sciences with wonderful colleagues who are committed to field teaching, and who have been actively engaged in developing field courses with topics that engage students interested in environmental science, but which also connect to geological sciences.

Field studies are place-based, and so there is no one-size-fits-all model to use in developing new field topics, but at our field station, in northwestern Wyoming, my colleagues have developed several unique projects. These include an analysis of water chemistry—particularly as a function of catchment of geology, measuring water temperature and observing ideal stream bed habitats, which are influenced by both the geologic substrate and its spatial patterns representative of Sevier fold and thrust belt development. Or an exploration of the elevational diversity of modern plants. The elevation diversity reflects temperature gradients, while spatial diversity may reflect substrate and soil type. Modern diversity can be compared to exposures of Eocene paleosols and paleobotanical collections to ask questions about long-term changes in temperature and aridity, and to probe the causes of those changes as tectonic or due to Cenozoic climatic changes.

Modern observations can be conceptually related to glacial outburst floods or pluvial lake floods during the Holocene, and the role of surface processes in shaping our planet through time can be assessed.

Many in this room could certainly come up with additional ideas, examples, and topics. Discussing and sharing ways in which we can retain fundamental earth science–oriented learning outcomes in field courses, while pivoting the subject matter in directions that are more closely aligned to current student interests, and the careers that they are likely to have, is crucial for the long-term continuation, and relevance, of field education.

I've thought a lot about the topics discussed so far, with regards to new technology and new topics, in part because my oldest daughter started college this fall. She is studying conservation biology at CU Boulder, and I am curious, and concerned, about what the world that she will graduate into will look like. I am also deeply aware that spending a month each summer of her life at our field station near Grand Teton and Yellowstone National Parks played no small role in the college major that she chose to pursue (today is also her birthday, so happy birthday, Zoe!).

In general, however, students have increasingly less exposure to earth sciences in secondary education, and participation in recreational outdoor pursuits is also in decline among many demographics. Raising student awareness around college programs and career opportunities in earth science is crucial. Once awareness is raised, creating a sense of community and belonging to attract students to the earth sciences is important to attract new students and diversify the population of students who are pursuing earth science degrees. Considering these challenges in the context of field programs is especially important.

We can perhaps take some lessons from programs that have had successes in this regard. Several institutions have established cohorting programs to introduce high school students to the earth sciences over progressive summers through both on-campus instruction and field education. These include GeoForce here in Texas at UT Austin, or Earth Camp at my own institution, the University of Michigan. These programs have a remarkable placement rate of high school students into STEM fields in college and increasing participation in the earth sciences through cohorting and community building..

At the next career stage, GSA's On To the Future program has had similar success, connecting undergraduate through early career geoscientists with mentors, peer groups, and professionals to build a sense of belonging in the earth science community.

At my own field camp, we teach both upper-level and lower-level courses in geology and environmental sciences. The upper-level field courses are populated by students in our major, who typically know one another from courses on campus, while it is much less likely that the students in the lower-level courses will know one another. We have recognized that issues of anxiety, isolation, and loneliness are more common among the lower-level students, who don't feel part of a cohort prior to arriving at our field station.

Proactively working to build such cohorts through multiple pre–field camp meetings, including informational sessions, social events, casual hikes, and overnight camping trips, are ways to help establish a sense of belonging and camaraderie, demystify the expectations of field camp, and build confidence in students that they have the skills and abilities to be successful in a field course.

That being said, it's also important to recognize that attending a field course in-person isn't a viable, or successful, strategy for everyone, and that there need to be alternatives to in-person field courses for students with accessibility, health, or travel limitations. A notable outcome of the COVID pandemic has been the persistence of several virtual field courses offered each summer, demonstrating the need and demand for virtual options. Some of these courses are "digital twins" of the projects undertaken by in-person field courses, while others are novel constructions of virtual geologic landscapes and problems inside of existing video game environments.

The GeoSPACE program at the University of Florida has developed a particularly novel approach to field teaching by developing a hybrid course, with in-person and fully virtual participants. The program is designed around the geologic themes of planetary geology and volcanology, with "astronauts" in the field and "mission control specialists" providing remote guidance and planning. Although designed specifically to address accessibility issues, one can see how such a model could be modified to remotely include students who are not able to participate in an in-person field camp for any other number of reasons.

Field education has been a core part of undergraduate education in the earth sciences because it's an ideal means by which to teach some of the concepts and learning outcomes which are most unique and fundamental to our field. With new tools and new technology available to us, it's time to think about how field education should evolve to meet the changing needs and interests of our students, and the future careers that they are likely to have.

GSA and its members have been at the forefront of supporting field education, building new field technologies, researching field education, and promoting field camp accessibility. I look forward to GSA continuing to lead in addressing the challenges presented to us in re-envisioning field education, and to increasing participation and accessibility to the unique opportunities that field education provides.