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Undergraduate learning in the field: Designing experiences, assessing outcomes, and exploring future opportunities

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ABSTRACT
Field learning experiences reach tens of thousands of undergraduate students annually, constituting their importance as components of undergraduate education and potential pathways for STEM education. Reports and planning efforts by national entities have highlighted the need to ground undergraduate field learning experiences in evidence-based practices, and to better understand the impacts of these experiences on students. In this study we describe the results of a national survey aimed at better understanding how instructors and directors at biological field stations, marine laboratories, and geoscience field camps are thinking about and designing programs, including learning strategies, student support, desired student outcomes, student assessment and program evaluation. This study is based on an online survey distributed in 2018 to a sample of directors and educators representing 163 undergraduate field learning experiences. The study achieved a satisfactory response rate of 31% ($n = 563$). The results of the study provide guidance on where support for improvement and research efforts should focus, including more intentional program design that considers student-centered and inclusive approaches and basic research on the impact of undergraduate field learning experiences on student learning more broadly (not just investigated in one program or course), both in terms of what the students learn (broadly defined) as well as how they learn, taking into account affective and cognitive gains. Such research can make productive use of the diversity of program types to investigate the link between student outcomes and student experiences.

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Introduction

> My [field station] experience helped open my eyes to the opportunities in the field and how science looks outside of a standard university laboratory.
>
> ~Student, Rocky Mountain Biological Lab

Students such as this one who participated in a summer research program at Rocky Mountain Biology Lab, engage in undergraduate field learning experiences in a variety of disciplines including general biology, ecology and evolutionary biology, earth sciences, and geology (Fleischner et al., 2017; Lohr et al., 1995; Mogk & Goodwin, 2012; Petcovic et al., 2014; Risser, 1986; Scott et al., 2012). A large number of the 450 institutions associated with the National Association of Marine Laboratories (NAML) and the Organization of Biological Field Stations (OBFS) support undergraduate field learning experiences (National Research Council (NRC), 2014). Furthermore, field camps traditionally serve as capstone courses in the geosciences (Drummond & Markin, 2008; Macdonald et al., 2005; Whitmeyer et al., 2009). Together, these institutions and programs serve a large pool of students, providing specific types of hands-on training not provided anywhere else in the undergraduate science education system (Hodder, 2009). Though highly valued, field learning experiences require high levels of resources (Petcovic et al., 2014) and are not equally accessed by all students (Gilley et al., 2015).

Both students and practitioners have suggested that investments in field learning experiences play a valuable role in undergraduate education, both for those going into the field sciences as a career and more generally for improving science literacy and connection to nature for a broader undergraduate student audience. However, few studies provide direct evidence about the potentially distinctive role that field learning experiences play in undergraduate STEM education (National Research Council (NRC), 2012, 2014). The "No-Child Left Inside" movement documented the value of outdoor experiences at the K-12 level (Gill, 2014; Louv, 2005) and initial assessment of field research experiences (Wilson et al., 2018) supports the value of field experiences for undergraduate students, but direct evidence is limited (Mogk & Goodwin, 2012). Furthermore, the

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diversity and complexity of undergraduate field learning experiences, which range from short field labs embedded in on-campus university courses to residential months-long field/marine research-focused experiences (Whitmeyer et al., 2009), make it challenging to document general outcomes. Nonetheless, they offer the opportunity to link specific program elements to specific student outcomes. Such information could be used to inform program design as well as to identify pedagogical best practices generally.

A number of possible mechanisms that link particular features of field experiences to learning have been identified, but most have been explored in the context of only one course. Stokes and Boyle (2009) for example, showed that students benefit from interacting directly with the environment when they learn to contextualize information, and when they develop subject-specific proficiencies and general skills, such as teamwork, decision-making and autonomy. Mogk and Goodwin (2012) concluded that learning in the field "produces affective responses that have a positive impact on student learning and helps initiate novices in the community of geoscience practice (p. 131)." Discovery-based and active learning pedagogies are key features of field learning experiences and have been linked to maintaining diversity in the sciences in a recent National Academy of Sciences report (NRC, 2014).

A potential mechanism linking features of field programs to learning is the immersive nature of the experience itself (Giamellaro, 2017; Jolley et al., 2018; Mogk & Goodwin, 2012). The Contextual Model of Learning (Falk, 2000; Falk & Storksdieck, 2005) recognizes that the physical, social, and personal contexts together influence a learner's experience. Similarly, the idea of an immersive experience takes into account the context, or whole situation, in which a person finds themselves. No clear definition of "immersive" has been articulated in the undergraduate field experience literature, but related ideas, such as embodiment (Nairn, 1999) and contextualization (Giamellaro, 2017) have been discussed to describe the significance of learning in the field. For the purposes of this study, we defined "immersive" as the opportunity for students to put their whole self into the experience: physically, socially, and emotionally. In this way, the living and learning environment and the object of study become one. Building on this idea, we use the term "extended" to reflect the importance of duration in these experiences. A better understanding of how the features of extended undergraduate field learning experiences, including the living and learning environment, impact student learning outcomes should inform the direction and support of field-based education programs, in particular those designed to broaden participation in field sciences.

Though conducting this research has been identified as a priority (NRC, 2014), limited expertise and funding have presented barriers. The Undergraduate Field Experiences Research Network (UFERN), funded by the Undergraduate Biology Education Research Coordination Network (RCN) program of the National Science Foundation, aims to advance research in this area and offers the landscape study presented in this paper as a catalyst. This study provides an overview of current program types and select design characteristics of extended undergraduate field learning experiences, which are of particular interest to the UFERN community

Research goals and questions

The overarching goal of the landscape study was to characterize programs that provide field learning experiences in the environmental sciences broadly defined (e.g., biology, ecology, evolutionary biology, earth sciences, and geology) and across the wide range of other disciplines involved in research at field stations and marine labs. We aimed to describe the average or typical program and the variation among programs, and to explore the factors associated with this variability. We also aimed to identify future opportunities for research that would guide and support these programs and contribute to the scholarship of undergraduate teaching and learning in place-based and field sciences. Our research questions about the undergraduate field learning experiences were:

1. What are the characteristics of extended undergraduate field learning experiences, including program type, design features, instructional strategies, desired student outcomes and assessment efforts?
2. How do program design features and their attributes vary between program types?
3. What are areas of future opportunities for informing the success of undergraduate field learning experiences?
4. What are future opportunities for conducting large-scale research across undergraduate field learning experiences?

For this study we have categorized field learning experiences into program types referenced as either a field course (i.e., a university credit course located off-campus), research experience (i.e., a program focused on research that may or may not provide university credits held at a professional research facility), or service learning (i.e., off-campus, often community-based programs that focus on service, learning, and reflection; Eyler et al., 1999). To characterize the potentially immersive nature of extended undergraduate field learning experiences across and within these program types, we present data about setting, residential aspect, and the duration and time of year of a program.

Methods

We administered a 37-item survey (see Supplemental materials) that was sent to program directors, instructors, and coordinators directly involved with extended field learning experiences. Survey items focused on collecting information about particular field learning experience features in order to characterize what is happening within these experiences throughout the USA and beyond. For this descriptive study, we used a basic survey method design: a cross-sectional one-time nonrandom sample of settings and programs that fall under the category of field-based education for the UFERN project. This landscape approach allows for a broad understanding of social or education systems to identify needs and future opportunities of the community involved (e.g., Laursen et al., 2013; Omasta, 2012; Yadav et al., 2015). The study reported here is part of a larger Landscape Analysis (O'Connell et al., 2018). The landscape study presented in this article aimed to characterize extended undergraduate field learning experiences and the needs of faculty and directors leading those experiences.

Sampling and study population

We used purposive and convenience sampling to reach the major organizations that were likely to include individuals involved in undergraduate field learning experiences. Accessibility to complete email lists for survey tracking purposes was a barrier. As a result, survey invitations were sent via listserv (without the benefit of email address tracking) and contacts as identified by the UFERN steering committee and members of the UFERN network (e.g., geosciences field camps, NSF-funded Research Experiences for Undergraduates site programs with an apparent field component) to get a broader perspective about extended undergraduate field learning experiences. Our study broadly defines field experiences to be inclusive of the interdisciplinary nature of research that occurs at field stations and marine labs and includes disciplines such as ecology, atmospheric sciences, geology, hydrology, geography, chemistry, and the humanities. In all we sent 553 email invitations to the survey on March 14, 2018. These email addresses were from:

- Organization of Biological Field Stations (OBFS) 2017 meeting participants (115 emails)
- National Association of Marine Labs (NAML) email contact list (77 emails)
- List of faculty participants in Geosciences field camps (170 emails)
- Long-Term Ecological Research (LTER) network members recommended by LTER Education & Outreach Committee (10 emails)
- List of faculty who received NSF Research Experience for Undergraduates (REU) site funding that were likely to have a field component as identified by the UFERN steering committee (181 emails).

Following the 553 invites, an additional 10 email addresses were obtained, from snowball sampling (recommendations of other respondents). Of the 563 targeted email invitations sent, 175 survey responses were received for a response rate of 31 percent. An additional 49 survey responses were collected less than a month later via distribution utilizing a link sent to a variety of listservs, such as Ecolog, Council for Undergraduate Research Community Forum, and OBFS. This additional effort brought total responses received up to 224; the total sampling population and response rate for these additional invitations is unknown given the anonymous link distribution.

Participants were invited to participate in the survey if they were directly involved with an extended undergraduate field learning experience at either a U.S. or international program site. The specific focus on "extended" undergraduate field learning experiences came from the interest of the initial community of scholars and educators who collaborated to develop the Research Coordination Network grant that funded this study. Because no agreed-upon definition exists of what constitutes an "extended" undergraduate field learning experience, we allowed potential participants in the survey to self-identify as such. Specifically, in the survey recruitment language, we invited them to take the survey, "If you are a program director, instructor, or coordinator directly involved in extended field courses, geology field camps, research experiences, or other kinds of structured field programs for undergraduates." Our aim was to include all field stations and marine labs in the U.S. as well as other undergraduate field learning programs.

Program sites

The study population was extended undergraduate field learning programs which we considered to be either field courses, research experiences or service learning programs at U.S. field stations and marine labs and other undergraduate field learning programs such as geosciences field camps and NSF-funded Research Experiences for Undergraduates (REU) site programs with an apparent field component. The faculty and staff directly involved in leading those programs were surveyed.

Survey development

Our study aimed to better understand the landscape of extended undergraduate field learning experiences in several key areas:

- Program design features and their attributes with a focus on the immersive experience
- Instructional strategies and learning activities
- Desired student outcomes

We identified potentially distinctive aspects of extended undergraduate field learning experiences based on literature, our own experiences, and the expertise of the UFERN steering committee. These ideas guided the development of the research questions for the larger landscape analysis study and the overall focus of the survey (e.g., residential aspect, duration, desired student outcomes).

Survey items were developed based on our research questions, a review of the literature about undergraduate field learning experiences, and discussions with an experienced team of directors and coordinators of undergraduate field learning experiences. Response options on survey items were not exhaustive, but instead were based on our knowledge of the literature and the expertise of the steering committee and members of UFERN (P. Chigbu, B. Cuker, L. Goralnik, T. Mourad, M. Storksdieck, personal communication, March 2018). All the items in the survey were reviewed by both social science researchers and directors/instructors of undergraduate field learning experiences and then piloted by two undergraduate field learning program directors before broad distribution.

The survey consisted predominately of close-ended items to ease participant burden. However, given the descriptive nature of the study, open-ended options for respondents to provide alternative answers beyond the list of close-ended responses were also included. Respondents were asked to report on their 2017 field year, self-selecting program details (e.g., program type, residential aspect, program activities, desired student outcomes, instructional strategies) as well as qualitative open-ended questions around pedagogy and evidence-based program design. The survey was pilot-tested, revised, and implemented on Qualtrics, a secure and established online survey tool.

Data for the study were included if the respondents self-selected as meeting the criteria of being directly involved with an extended undergraduate field learning experience (per question at the beginning of the Qualtrics survey) and if they completed more than 20% of the survey with useful information, meaning they did not fill out multiple questions with NA as a response.

Data analysis

The survey dataset was exported from Qualtrics as an Excel file, cleaned, and imported into IBM SPSS software for statistical analysis.

Descriptive statistics (i.e., sums, frequencies, means, median, standard deviations, skewness, kurtosis) were used to explore the variability of undergraduate field learning experiences across all program types represented in the survey. Non-parametric tests were used when assumptions were not met because of missing data and non-normal distributions. A Chi-square test was used to determine an association between program type and instructional strategies. Given the few service-learning programs and self-identified responses as "other," and the focus of the study on extended field learning, only field courses and research experiences were included in comparisons of proportion between program types. Mann-Whitney U tests were used to compare desired student outcome variables and instructional strategies between the two program types, field courses and research experiences. Analyses did not include missing data, employing listwise deletion, and all analyses were considered significant with a $p \geq 0.05$.

Results

In this section we first profile the people who responded to the survey, then present results as guided by the research questions for the study.

Profile of survey respondents

From the 224 survey responses, useable data was gathered from 143 individual respondents about 163 undergraduate field programs (20 individuals provided information on two programs). An additional 17 respondents were not directly involved in field programs, and 64 gave incomplete responses. Overall response and completion rates cannot be determined since the survey was sent as a link through listservs and other distribution channels not allowing for email address tracking. The response rate for surveys sent to individual recipients was 31%.

Responses to the survey came from institutions in every state in the U.S. except North and South Dakota, Idaho, Mississippi, Vermont, Connecticut, and Rhode Island. California had the largest representation of institutions compared to other states, with eleven institutions. Many of the programs described in survey responses have impressive longevity, with one third existing for at least 40 years, while another one third were less than 10 years old. Respondents listed themselves as Directors (54%), Lead Instructors (32%), and/or Coordinators (16%) with 52 respondents indicating more than one role (e.g., Director and Associate Professor).

Characteristics of extended undergraduate field learning experiences

Figure 1 illustrates the variety of undergraduate field learning disciplines represented in the survey. Geology ($n = 62$) and ecology ($n = 59$) predominate the represented disciplines, followed by Earth and Environmental Sciences ($n = 18$). For two of the reported undergraduate learning experiences, the discipline was unclear.

The number of responses per program type varied across the four survey options (Table 1). The majority of respondents in our sample self-identified their program as either field courses or research experiences. Three respondents described their programs as service learning and the remaining respondents (6%) selected "Other," and wrote in responses best described as some combination of these categories. Given the low number of responses self-identifying their program as service learning or "Other," only research experiences and field courses are further analyzed in comparisons of program types.

Class or cohort sizes varied between and within program types. Among the respondents who reported participant totals, 79% reported having fewer than 40 student participants in 2017, though the range of student participants across programs was wide (2–658 students). The overall mean of student participants was 42 per program ($SD = 84$), but elevating the mean was a small handful of very large field programs with 500 or more participants. These high numbers of participants might have been university courses that were taught in smaller cohorts across time. We asked for a reporting of participants during the year 2017, but did not ask specifically about whether the programs were repeated multiple times during that year. On average, field courses had more participants ($M = 47$, $SD = 86$) than research experiences ($M = 11$, $SD = 9$), though research experiences had less variability between programs. See the complete landscape analysis report for information about

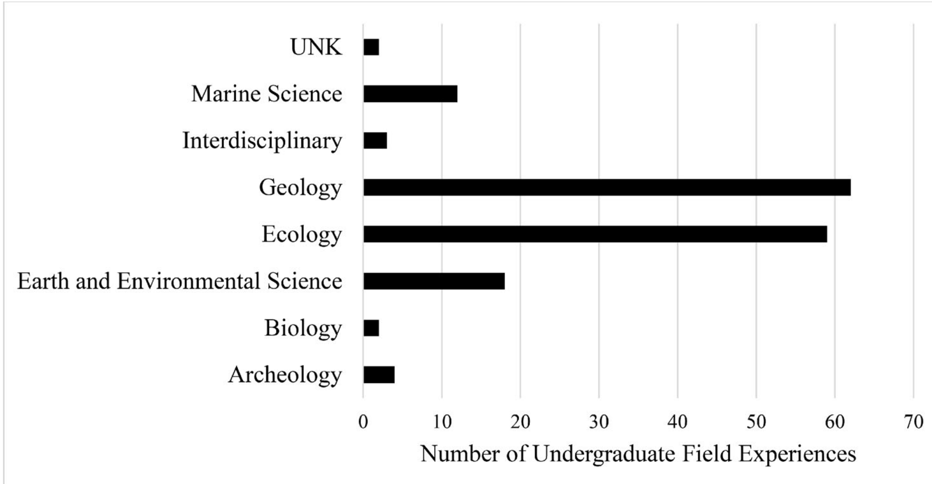

Figure 1. Frequency of discipline as represented in survey. This figure illustrates the various disciplines represented in the survey and the number of responses within each of the disciplines. N = 162. *Note:* Data are from the 162 responses/programs with student participant numbers reported.

Table 1. Frequency of Program Type as represented in survey and the median and range of reported participants per program type.

Participant medians per program type and number of programs per type				
Program types	Total programs	Median participants per program type	Min	Max
Field course	99	22	2	658
Research experience	51	9	2	48
Service learning	3	100	9	547
other	9	75	12	250

Note: There are 162 programs who reported participant totals, rather than the 163 total programs.

demographics of undergraduate field learning experiences (O'Connell et al., 2018).

Immersive experience

Setting

A majority (60%) of the undergraduate field learning experiences described in the survey took place at field stations, marine labs, geology camps or residential research sites, while 24% involved traveling to different field sites (including a small number of "At Sea" field programs).

Residential aspect

A large number of programs (83%) were either residential or traveling in nature (Figure 2). Students lived together with other students (co-residency) in all but one of the residential and traveling programs. Between the two program types, only a small number of residential research experiences involved students and faculty living together, while field courses were commonly designed as residential and with students and researchers co-residing. Traveling was also more common among field courses than research experiences. All three of the service learning programs indicated that they were designed as neither residential nor traveling.

Duration and time of year

The average program duration across all program types was 10 weeks ($M = 10$; $SD = 13$), with fewer than eight percent of programs indicating duration longer than one year for the 2017 program year. Research experiences ($M = 14$ weeks; $SD = 11$) were longer in duration on average than field courses ($M = 7$ weeks; $SD = 10$). A large number of programs occurred during the summer only (114 programs or 70%), while another 22 programs (13%) occurred both in the summer and academic year.

Major learning activities and instructional strategies

Overall, respondents indicated that students in their programs are spending a large portion of their time engaged in "Independent, mentored, small group research (study design, literature review, data collection, and analysis, writing, and presenting)," and this result is consistent across field courses and research experiences (59% and 89%, respectively reporting > 50% time spent, see Table 2). A higher percentage of field courses versus research experiences spent time on direct instruction, which is to be expected given the contrasting nature of the two program types. Research experiences reported dedicating significant time to career exploration and research skill development activities compared to field courses, with students in 64% of the field courses actually spending no time on career counseling and professional competencies. Nearly 50% of field courses and 30% of research experiences do not incorporate social or recreational time in their formal program activities, with the remainder of both program types including small to moderate amounts of time to these activities. Respondents shared examples of extra-curricular activities including field trips

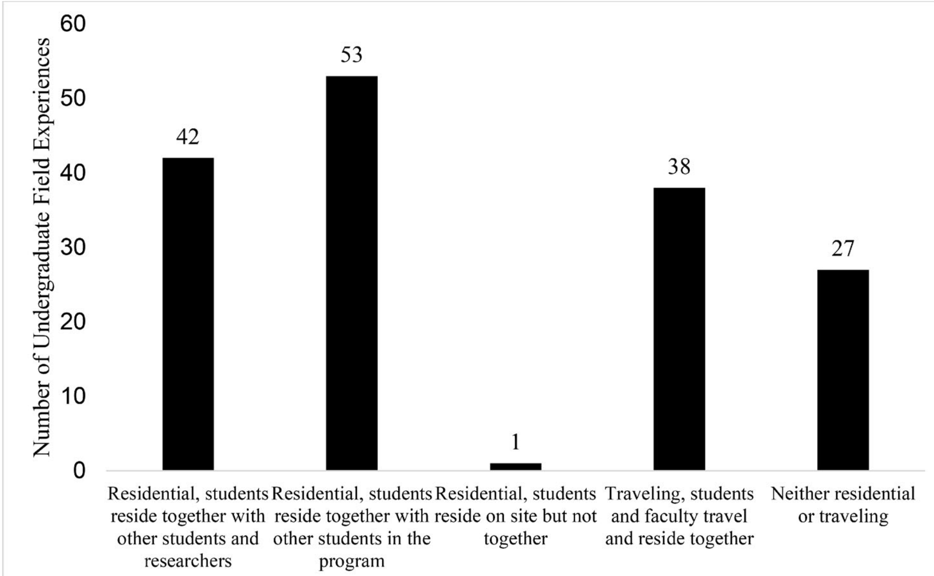

Figure 2. Frequency of reported extended undergraduate field learning experiences by residential aspect as categorized in survey. This figure illustrates the number of programs who reported how students resided, or not, within the programs. *Note:* Only 161 programs answered this survey question.

Table 2. Percentage of responding programs and indicated different amounts of time spent by students (as reported by faculty) on the five main types of program activities queried in the survey, for field course (FC) versus research experiences (RE) program types.

Amount of time spent on major student activities	Program type	
	FC	RE
Research		
no time	7	0
1–50% time	34	7
> 50% time	**59**	**86**
Direct Instruction		
no time	4	16
1–50% time	**77**	**53**
> 50% time	19	2
Career Exploration		
no time	**64**	27
1–50% time	36	**73**
> 50% time	0	0
Research Skills		
no time	39	16
1–50% time	**56**	**82**
> 50% time	5	2
Social		
no time	48.3	31.3
1–50% time	**49.4**	**68.8**
> 50% time	2.3	0

Numbers in bold indicate the highest percentage of time within one of the five main types of program activities for either field courses or research experiences. N = 163.

and independent exploration or activities like snorkeling or walking/hiking.

We asked programs to report on the use of some of the particular pedagogical or instructional strategies that they used during their programs (Table 3). The strategies were not an exhaustive list, but were chosen to represent commonly used strategies when designing and implementing field learning experiences, with consideration for inclusivity of underrepresented students. For ease of interpretation and visualization of the results, we divided the strategies into those supporting *content* of the course experience, those supporting the process of learning (*pedagogy*), and those supporting the students' overall experience (*context*). Programs were asked to report if they explicitly used these strategies "not at all, a little, a moderate amount, and "a great deal," and if they would like to "use this strategy more or better."

Table 3 (below) paints a complex picture about use of instructional strategies since some content-related strategies were present at a relatively high rate, while some pedagogy and context-related strategies were reported infrequently, indicating room for increased awareness and use of these strategies. For instance, providing "written guidelines for expectations for mentors/instructors and/or students" was a widely used strategy overall, a context related strategy, whereas, "provide diversity training" was the least widely used overall, also a context related strategy. Looking at all program types, there were three of the strategies where there was an association between strategy used and program type. However, between field courses and research experiences only the strategy, "give students choice (about research project topic, about mentors, etc.)" was statistically significant (with Bonferroni correction), with research experiences reporting higher use of the strategy ($U = 793.5$, $p = 0$). Overall, the frequency of programs that wanted to "use this strategy more or better" ranged only from 6 to 22% (O'Connell et al., 2018), indicating a low desire to change the strategies currently used. For a complete discussion of the extent to which respondents explicitly used these strategies and their interest in "using this strategy more or better," refer to O'Connell et al. (2018).

Desired outcomes for students and guiding evidence for programs

The three most commonly chosen desired student outcomes among all the programs were those related to knowledge and skills, followed by a "greater sense of belonging in the

Table 3. Frequency of the strategies used per program type for supporting *content* of the course experience, those supporting the process of learning (*pedagogy*), and those supporting the students' overall experience (*context*).

Percentages reported by field courses and research experiences on the use of strategies for supporting the learning environment

	Strategies	Field courses	Research experience
Content	Connect research or program topic to careers ($n = 139$)	62%	82%
	Incorporate Traditional Ecological Knowledge or other alternative ways of knowing ($n = 140$)	25%	13%
	Connect the program topic to local/community problems or issues ($n = 140$) §	45%	54%
	Connect the program topic to large-scale problems or issues ($n = 140$)	60%	76%
Pedagogy	Collect information from the student participants before the program starts and use it to inform program design ($n = 143$)	16%	33%
	Provide mentoring system where students support each other (e.g., near-peer mentoring from program alumni) ($n = 139$)	26%	32%
	Provide pre-program training and/or support for students to prepare them for success ($n = 143$)	42%	45%
	Give students choice (about research project topic, about mentors, etc.) ($n = 140$) §,**	34%	81%
Context	Provide written guidelines of expectations for mentors/instructors and/or students ($n = 140$)	82%	78%
	Develop formal agreements with students and/or mentors/instructors such as code of conduct and code of ethics ($n = 140$)	69%	52%
	Provide clear and safe pathways for addressing individual and group concerns ($n = 142$) §	67%	66%
	Provide diversity training to students and/or mentors ($n = 141$)	10%	26%
	Provide need-based support to address disparities in student resources ($n = 139$)	44%	41%
	Include opportunities for students to interact with mentors, instructors and/or other experts from groups underrepresented in STEM ($n = 137$)	36%	54%

Programs were asked to report if they explicitly used these strategies "not at all, a little, a moderate amount, and "a great deal." Frequency is presented in this table as programs that reported either "a moderate amount," or "a great deal." We made the assumption that these two categories most conservatively represent programs actually implementing the strategy. N = 163.

Notes: § indicates an association between program type and strategy used using a Ţ^2 analysis across all program types (Bonferroni adjusted p-value), **$p < .001$ using a Mann-Whitney U test to compare proportions between field courses and research and experiences (Bonferroni adjusted p-value).

scientific community," "stronger professional skills," and "increased interest in a career in field-based science and general STEM field," which were weighted equally (Table 4). The top three desired student outcomes were selected by 87% or more of the respondents. Only 9% of total respondents did not indicate an "increased understanding of specific concepts and content" as a desired student outcome. The proportion of programs collecting evidence on interest in general STEM careers was greater among research experiences. In contrast, desired student outcomes related to sense of place and connection to nature were chosen by 46% or fewer of the respondents.

Fewer than 30 respondents offered additional desired student outcomes beyond the provided list. The unique responses were:

1. Love for nature, intense respect for the environment, commitment to sustainability
2. Ability to live and work in primitive or adverse camping conditions
3. Listening and being still
4. Increased self-confidence in STEM abilities
5. Generation of research products
6. Exposure to approaches outside their own discipline
7. Increased connection to the K-12 community
8. Increased awareness of scientific ethics

More than half of the respondents across all program types are collecting empirical evidence for the three most commonly chosen desired student outcomes (Table 4). In contrast, under 20% of the respondents who desired student outcomes of "Increased respect or care for the environment," "Stronger connections to place," or "Increased stewardship intention or behavior" collected evidence about those outcomes. This lower rate of collection of evidence for these outcomes is notable in that these are outcomes likely to be distinctive to *field* learning experiences as opposed to an *indoor* lab or classroom based undergraduate courses and research experiences. Also noteworthy is that "greater sense of belonging in the scientific community" ranked 4th as a highly desired student outcome across all programs with 76% of respondents choosing it, yet only 17% indicated they are collecting evidence on this outcome and 36% checked the "no, but would like to" response. Respondents indicated highest interest in collecting evidence about "increased sense of connection to local/community problems or issues," "increased respect or care for the environment," and "increased stewardship intention or behavior" (Table 4).

The ways in which respondents use the empirical evidence is summarized in Table 5. Overall, a large number of respondents reported using empirical evidence to make changes in program design to improve student experiences and to improve instructor/mentor experiences. Less common is the collection of empirical evidence to make changes to the application process or to make changes to recruitment, and 18% or fewer of the programs were even interested in using evidence for the recruitment and application process. Only 22 programs (13% of total programs) reported the use of prior evidence to guide future programs across all four ways (improve student experiences, improve instructor/mentor experiences, changes in the application process, and changes in the recruitment process), supporting a more holistic approach to program design.

Table 4. Ranking of desired student outcomes for all programs (most commonly chosen to least commonly chosen) as selected from provided list.

Ranking of student outcomes and collection of evidence on outcome (or interest to collect)

	Are you collecting evidence of the student outcome?					
	Field course			Research experience		
Ranked student outcomes	Yes (%)	Like to (%)	No (%)	Yes (%)	Like to (%)	No (%)
1. Increased understanding of specific concepts and content ($n = 148$)	**61**	23	16	40	30	30
2. Stronger skills in discipline-specific procedures ($n = 144$)	**61**	17	22	**51**	21	28
3. Increased understanding of and proficiency with research practices ($n = 141$)	**65**	17	18	**64**	19	17
4. Greater sense of belonging in the scientific community ($n = 123$)	17	36	47	40	36	24
5. Stronger professional skills ($n = 123$)	41	32	27	**52**	34	14
6. Increased interest in a career in general STEM field* ($n = 121$)	10	43	47	**56**	32	12
7. Increased interest in a career in field-based science ($n = 102$)	21	31	48	**61**	26	13
8. Stronger connections to place ($n = 99$)	14	35	**51**	23	39	39
9. Increased respect or care for the environment ($n = 90$)	14	45	41	15	**50**	35
10. Increased stewardship intention or behavior ($n = 80$)	16	43	41	12	**52**	36
11. More refined career goals ($n = 78$)	19	43	38	**53**	31	17
12. Stronger development as informed citizens ($n = 76$)	25	33	43	15	**56**	30
13. Increased sense of connection to large-scale problems or issues ($n = 75$)	16	42	42	26	42	32
14. Expanded professional networks ($n = 73$)	26	36	39	49	32	19
15. Increased sense of connection to local/community problems or issues ($n = 53$)	17	44	39	14	**64**	23

Percentage of programs who report collecting evidence of outcome or would like to within field courses and research experiences and those who reported they are not collecting (and are not interested in collecting). Numbers in bold indicate where more than 50 percent of programs responded to either collecting, would like to collect, or not collecting evidence of outcome.

Notes: *$p < .002$, using a Mann-Whitney U test (Bonferonni adjusted p-value) to compare proportions between field courses and research and experiences.

Table 5. Percentage of respondents reporting overall, across all program types, as to their use of empirical evidence to guide their work, and the percentage of respondents within each of the program types, field courses, and research experiences. N = 163.

Use of empirical evidence to guide future program design across all program types and within field courses and research experiences

	All program types	Field courses	Research experiences
To make changes in program design to improve student experiences (%)	$n = 147$	$n = 89$	$n = 48$
Yes	69	73	45
No	16	12	41
No, but would like to	14	15	14
To make changes in program design to improve instructor/mentor experiences (%)	$n = 147$	$n = 89$	$n = 48$
Yes	60	66	48
No	22	20	27
No, but would like to	18	14	25
To make changes in the application process (%)	$n = 148$	$n = 89$	$n = 49$
Yes	35	30	45
No	52	58	41
No, but would like to	13	11	14
To make changes in recruitment (%)	$n = 148$	$n = 89$	$n = 49$
Yes	34	33	37
No	49	52	45
No, but would like to	18	16	18

Discussion

A recent NRC report (NRC, 2014) recommended that field stations and marine labs "identify and support the development of … educational assets … by bringing together scientists from a number of disciplines, including the social sciences" (p. 2), and "work together to develop a common set of metrics of performance and impact … that can be aggregated for regions and the entire nation (p. 6)." This study contributes to this effort by exploring the nature of extended undergraduate field learning experiences. The results begin to identify patterns of practice and need, thereby revealing future opportunities for research that will optimize the development and implementation of extended undergraduate field learning experiences.

Given the lack of clear definitions, the current landscape of what constitutes extended undergraduate field learning experiences is diverse and complex. Not all programs fit a pattern or mold. A majority of programs, however, offer students extended undergraduate field learning opportunities that on average are over 10 weeks, occur primarily during the summer, and entail residing with other students and/or researchers at either a field station, marine lab, geology camp, or research site. These common features thus open the door for comparison of student outcomes across types of field learning experiences.

Immersive experience

Aspects of immersive program design could have a major impact on the student learning experience, and below we discuss how variations in residential aspect, setting, and duration among field learning experiences could lead to future areas of research.

The setting of the majority of programs in the study included some form of a co-residential aspect, either traveling and co-residing or extended duration in one setting and co-residing. This might provide an interesting focus of comparative research, either across otherwise similar programs of each setting, or crossed with field courses versus research experiences. The nature of the setting of a field experience can have important implications for student engagement both with the landscape and with course content, supporting the physical, social, and emotional immersive aspects of learning. Jolley et al. (2018) found that students who participated in a course module which involved studying a single site near an isolated field station developed a stronger place attachment and demonstrated stronger alignment between student perceptions of learning and instructor intentions for learning than when those same students participated in a traveling module that involved staying at a field station in a suburban area and studying several roadside sites. The residential aspect of field learning experiences also has implications for learning and community. The unique social dynamics of field activity deepen conceptual learning (Stokes & Boyle, 2009; Whitmeyer et al., 2009) and promote the development of students' identity as scientists as part of a scientific community of practice (Mogk & Goodwin, 2012; Streule & Craig, 2016). However, the residential aspect of these learning experiences can create high incidences of sexual harassment and assault (Meyers et al., 2014) and isolation of students of color due to a lack of role models and peers (O'Connell & Holmes, 2011; Steele & Aronson, 1995). It is also a time and financial barrier for some students of need, and for students who are unfamiliar and therefore potentially uncomfortable in nature and nature-near settings.

The amount of time students spend immersed in the experience potentially has implications for community-building, development of sense of place, and also encompasses instructional time, the impact of which is not equal across students (Hayes & Gershenson, 2015). The average reported duration of 10 weeks for the extended field experiences described in this study is likely driven by the typical length of summer breaks for undergraduates and possibly driven by the requirements of NSF programs funding many research experiences. The impact of duration on the student learning experience merits further exploration as a research focus. Specifically, such research could investigate the extent of how duration contributes to student outcomes, in what ways, and for whom. For example, can programs of shorter duration achieve some of the same student outcomes as more extended programs, and thus serve a population of students who are not able to participate in extended programs? Extended engagement with students beyond the summer is another component of program duration that was explored in this study. Many summer programs reported offering continued mentorship by faculty or instructors during the academic year. Hernandez et al. (2018) found that persistence in science by students from underrepresented groups required sustained engagement of 10 or more hours for at least two semesters following a summer experience. Likewise, field trips that were augmented by on-going activities allow for more student-centered (e.g., Baeten et al., 2010; O'Neill & McMahon, 2005) and project-based learning to take place (e.g., Charlton-Perez, 2013; Kahn & O'Rourke, 2004). Considering the large proportion of undergraduate field experiences with a residential aspect and the extended duration and the potential for impact on STEM pathways these immersive experiences warrant further research on student learning across a multitude of student demographics and factors. For further discussion and references about setting, residential aspect, and duration, refer to Jolley et al. (2018) and Lonergan and Andresen (1988).

Major learning activities and instructional strategies

Students engage in independent, mentored, or small group research during both research experiences and field courses, spending more time doing research than receiving direct instruction of science content in both program types. The active, hands-on process of doing research aligns with the recommendations outlined in the Vision and Change in Biology Report (American Association for the Advancement of Science, 2011), which calls on undergraduate biology educators to use active-learning, inquiry-driven, and relevant pedagogies. The Vision and Change report highlights research experiences as an integral component of efforts to reform undergraduate biology education and the recent NRC Report on Undergraduate Research Experiences for STEM Students (National Academies of Sciences, Engineering, and Medicine, 2017) summarizes the evidence of the positive impact of these learning experiences and the critical role they play in training a more diverse cohort of the next generation of scientists. This research component of both types of programs reaffirms the valuable role these experiences play in providing research opportunities for students.

The full Landscape Analysis report (O'Connell et al., 2018) shows that a higher number of students participated in field courses compared to research experiences, including both freshman and sophomore STEM and non-STEM students. This result suggests that field courses have the potential to or are already serving as pathways to developing interest in field-based sciences and STEM in general. Similar to Course-Based Undergraduate Research Experiences (CUREs), the format and size of field courses creates an opportunity to make research accessible to more diverse populations of students (Auchincloss et al., 2014). Broader accessibility provides an opportunity to recruit and, if the experiences are well designed with positive outcomes, increase persistence of underrepresented students in STEM, as well as foster science literacy for non-STEM majors. More research is required to explore the extent to which engagement in either field courses or research experiences can or does serve as a sequence for student engagement and/or advancement/retention.

This study showed that directors, instructors, and coordinators of undergraduate field learning experiences are incorporating a diversity of activities and instructional approaches in their programs. For example, many field courses and research experiences provide written guidelines of expectations for mentors/instructors and/or students. Connecting research or program topic to careers is another commonly used strategy for both program types. Research experiences commonly used the strategy of "giving students choice," but this was not the case for field courses. The mentoring and apprenticeship model of research experiences (Linn et al., 2015) likely lends itself to more flexibility in program design and gives students choice and autonomy over research project topic and mentors. However, program leaders are not taking full advantage of information available in the education literature on strategies for designing and implementing learning experiences, especially those that are inclusive or that support learning experiences for a diverse range of participants (Table 3). This result is not surprising given that STEM faculty members generally don't receive training in interpreting or conducting education research (NASEM, 2017) nor are they trained in pedagogy the same way that K-12 teachers are, for example.

Desired outcomes for students and assessment efforts

The primary role of field courses and research experiences in the STEM curriculum is to provide students with hands-on practice in *doing* disciplinary work. Therefore, it is not surprising that the highest ranked desired student outcomes were related to developing students' disciplinary knowledge, skills and abilities (discipline-specific skills, research practices, conceptual knowledge) and that these are the areas where the majority of the outcomes data are currently being collected (Table 4). Outcomes that often are associated with engaging and retaining diverse students in the STEM workforce, including affective outcomes such as increased sense of connection to local/community problems; and social outcomes such as increased sense of belonging in the scientific community, were less frequently highlighted as intended outcomes by survey respondents.

Stronger connections to place was considered a desired student outcome by 67% of survey respondents, and they aspire to collect evidence to document this gain among students. However, they currently are less likely to evaluate this outcome directly in their courses and programs. Sense of place is a term "that describes a person's connections with a place through their attachment to it and meanings they see within it" (Brandenburg & Carroll, 1995; Jolley et al., 2018, p. 652, see also Tuan, 1977; Semken & Freeman, 2008; Williams & Stewart, 1998). Researchers have shown positive connections between sense of place or similarly, connections with Earth, and motivation to learn field science content (Jolley et al., 2018; van der Hoeven Kraft et al., 2011). Because respondents in this study expressed interest in collecting more evidence around connections to place and environmental education-focused outcomes, especially within research experience programs, good use could be made of existing resources from the environmental education community, which has long focused on elements of community and placed-based values (Wals et al., 2017). Building these connections would represent a low-stakes investment that the field science education community could make to improve the overall effectiveness of their field courses and research programs (Mogk & Goodwin, 2012).

The value of affective development in undergraduate students has been well documented (e.g., National Academies of Sciences, Engineering, and Medicine (NASEM), 2016; Petcovic et al., 2014; Stokes & Boyle, 2009). Jolley et al. (2018) discussed the need for consideration of the affective domain (attitudes, emotions, and values) in undergraduate field learning experiences because of the complexity of field environments such as inclement weather and potential injuries and accidents (Stokes & Boyle, 2009). Survey respondents reported that they considered affective outcomes such as sense of belonging, interest in career, and stronger professional skills valuable and aspired to collect evidence about the achievement of these outcomes, though these outcomes were less likely to be addressed or evaluated directly. Further research aimed at understanding how programs built around connection to place and development of interest and identity may influence *how* students learn, as opposed to *what* students learn is needed. In addition, research on how attention to the development of students' affective attributes serves to recruit, support, and retain underrepresented populations of students is an avenue for future research. Evidence that value-based socio-emotional learning can reduce the achievement gap (Harackiewicz et al., 2016) in underrepresented minority populations in STEM fields suggests this line of research could reveal program features key to broadening participation in field learning experiences.

Supporting change

We identified two promising strategies in particular for engaging students from diverse backgrounds that could be used more extensively in field experience programs (Table 3). (1) Including mentors/faculty/invited speakers from underrepresented groups can be very important in providing role models for students and help achieve greater diversity (Clavijo & Chandler, 2003). This strategy was used infrequently in field courses, but this could be relatively straightforward to address (at least where faculty of color or from other underrepresented groups are available to participate at reasonable cost and effort). However, we acknowledge that the remote nature of field stations may limit this opportunity. (2) Collecting student information prior to the start of the program and using it to inform program design supports a student-centered approach by tailoring the experience to students' strengths, aspirations and needs. Only about one in six field courses and about one-third of the research experiences reported that they used this strategy (Table 3). It is critical to think about how the goals of a diversity of student populations might be addressed within the program design (Blockus, 2016; Dolan, 2016), and collecting pre-program information from students could be relatively straight-forward to implement.

Fortunately, some survey respondents, especially those teaching field courses, already report using an iterative design process to develop courses and programs, and they seem engaged in extending the use of empirical evidence to refine programing. However, these evidence-based design and improvement efforts do not seem to extend to all salient aspects of the student experience. For instance, fewer than 50% of respondents report that they are using evidence to make changes in recruitment or the application process, and approximately half are not interested in using evidence to improve these processes at all. Particularly for research experiences, which tend to involve far fewer students, the recruitment, application and selection process should be considered very carefully for inclusion, access, and equity reasons (Bangera & Brownell, 2014; NASEM, 2017; Pierszalowski et al., 2018).

In general, directors, instructors, and coordinators expressed more interest in collecting evidence around practices and outcomes than in changing to incorporate instructional strategies that support students' learning experience. In the full landscape analysis report, respondents requested getting help with collecting evidence about study outcomes by learning what others in the field are doing, getting access to example instruments, and "how-to help" around capturing complex student outcomes (O'Connell et al., 2018). Additional support will be needed to help leaders turn student data into program improvement and to make the more substantial changes in program structure and delivery that may be called for, something best supported through targeted professional learning associated with community support (Bryk et al., 2011).

Limitations

The research team made every effort to reach out to a broad range of communities and professional associations with members involved in undergraduate field programs, but given the overall low response rate expected of online and email based surveys, final recruitment may not accurately reflect the undergraduate field program community as a whole. Certain individuals may have been more likely to see the survey recruitment or more motivated to respond based on familiarity or prior connection with the UFERN principal investigators. As a result, we do not claim that the results are fully representative for the field. It is prudent to assume the sample is biased toward successful programs and respondents that are more engaged in reflection and inquiry about their programs and practice than the average program director, coordinator or mentor might be.

UFERN leadership and input from advisors were used in developing the survey and establishing the list of responses per item. However, we did not provide definitions of key concepts in the survey, including what even constitutes a field program. For instance, the term "extended" was used to characterize the target programs for the study, but the term still has not been adequately defined beyond our proposed definition for this study, post survey. Similarly, the differing program types (field course vs. research experience vs. service-learning program) may be loosely established terms within the field, but full agency was given to the respondents in defining where their programs fit. The UFERN community will use this data to craft and fine-tune these definitions to align definitions across future research projects. Nonetheless, ambiguity in the meaning of terms is a threat to internal validity, and need to be considered when interpreting the quantitative results presented here.

Conclusions and implications

This study describes a rich landscape of extended field learning experiences for undergraduates in the field-based sciences. Field courses that feature direct instruction in field science and methods were revealed to dedicate significant time to research as well, and with their larger enrollments, may play an especially important role in engaging students in immersive field learning. Research experiences engage smaller numbers of students in more self-directed learning. The possibility that students might move from shorter field experiences (not described in this study), through field courses and then research experiences is intriguing, and poses both an exciting research challenge and an opportunity for the community to articulate pathways of engagement and development for a diversity of students. There is much yet to understand about undergraduate field learning experiences, and our study provides guidance and support for the development of a framework and research agenda for the interdisciplinary community of practitioners and scholars in general, and the NSF-funded UFERN project in particular.

The results of this research can be used by the community to develop resources that support field course and research experience directors to engage in intentional program design and evaluation and that empowers them to use evidence of student outcomes to iteratively improve their programs. Collection of such evidence may be accomplished using common instruments designed by the community that would allow investigation of the impact of these learning experiences across field stations and the impact of collective efforts to broaden participation to populations currently underrepresented in field sciences.

The results of the study provide some guidance on where improvement efforts should focus. A need exists for more intentional program design, in particular considering student-centered and inclusive approaches, and supporting student outcomes that are stated but not programmed for through intentional program design. A need also exists for professional development around student learning, evidence-based practices in support of all students, student assessment and program evaluation for program and site leads and instructors.

The results of the study also provide guidance on where research efforts should focus. A need exists for basic research on the impact of undergraduate field learning experiences on student learning more broadly (not just investigated in one program or course), both in terms of what the students learn (broadly defined) as well as how they learn, taking into account affective and cognitive gains. Such research can make productive use of the diversity of program types to investigate the link between student outcomes and student experiences. In order to encourage and support this kind of research, validated assessment instruments that can be applied across a diversity of program types need to be developed. Data from this study can provide a starting point for prioritizing such assessments

Finally, a need exists to better understand how program and site leads and instructors might best be supported. Various conceptual frameworks exist that can be applied to support community learning, such as Communities of Practice (Lave & Wenger, 1991; Wenger, 1998; Wenger et al., 2002), networked improvement communities (NIC) (Bryk et al., 2011) or collective impact communities (Kania & Kramer, 2011). These, or other forms of support systems, might be useful to consider when designing common strategies across many field experience sites and programs.

Aside from providing insights into a potential gap between student outcomes and experience design, and desire for improvement vs prioritization of associated action, this study provides yet another example of the challenge many natural and physical scientists face in the arena of education or public outreach. At the end of the day, many are tasked to engage in professional practices for which they did not receive initial training and education, or ongoing support for professional growth. In that, the situation we report for undergraduate field experiences is not fundamentally different than that of undergraduate STEM education or science outreach in general. The gaps and challenges identified in this study provide a road map that collective action and collaboration with education scholars and practitioners can address together with a shared commitment to providing high quality field experiences to undergraduates.

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