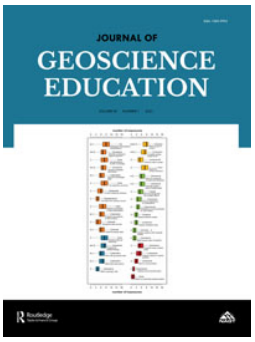

Journal of Geoscience Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ujge20

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JOURNAL OF GEOSCIENCE EDUCATION
2021, VOL. 69, NO. 1, 85–95
https://doi.org/10.1080/10899995.2020.1838850

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Activation of the Multicontext model in a field-based program for traditionally underserved students

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ABSTRACT

This paper presents results from our multi-year NSF-IRES program: a four-week, field-based summer program involving the participation and mentorship of U.S. undergraduate geoscience cohorts to develop knowledge and skills in sedimentary geology while immersed in an international research collaboration. Student participants in our program are predominantly first-generation college students, largely from historically underrepresented groups in STEM, and most have a “high context” orientation. Academic culture (especially in STEM) tends to favor the “low-context” approach of scientific inquiry (task-oriented, linear, individuated), but many students bring different cultural values from personal or community-based experiences that tend to be higher-context (process-oriented, systems-thinking, integrated). Herein we discuss how activating a Multicontext model—one that recognizes and includes a broader spectrum of “knowing and doing”—resulted in measurable advances, especially for higher-context students, from the first to second year of the program in terms of self-efficacy in field and analytical competencies, as well as in student engagement. To balance cultural frameworks, specific implementations in the field curriculum included (1) a non-linear, learning cycle-structured orientation prior to fieldwork that clearly introduces research objectives early, and promotes scientific inquiry and peer-to-peer interaction, (2) frequent discussions during fieldwork to place low-context tasks such as making field measurements into a broader context, and (3) a pre-defined mini-project option that allows students to set an individual intent for growth as a scientist in this experience. Leaders of similar programs to NSF IRES that support undergraduate students from underrepresented groups in STEM research might enhance program quality, student engagement, and inclusivity by recognizing and adapting to a broader spectrum of culturally-based learning perspectives. This study represents a small segment within the Multicontext system for redefining and expanding diversity and inclusion—a theory that has broad implications for the entirety of academic culture.

ARTICLE HISTORY
Received 22 November 2019
Revised 29 August 2020
Accepted 10 October 2020

KEYWORDS
Context diversity; Multicontext; undergraduate geoscience education; 5E learning; field education

Purpose and learning goals

At all degree levels, the geosciences remain the least diverse of all STEM fields, with almost no change in number of geoscience PhDs attained by Native American and Black (non-Hispanic) minorities in over 40 years (Bernard & Cooperdock, 2018; Dutt, 2020). Weissmann et al. (2019), Chávez and Longerbeam (2016), and Ibarra (1999, 2001) describe how activation of Multicontext Theory can broaden academic (and geoscience) culture to create an inclusive environment that values a *spectrum* of cultural strengths for all students. Participants in our month-long, summer field program (NSF-IRES) are students from racial/ethnic minority groups, low socioeconomic status, and/or are nontraditional students, and mostly have a “high context” orientation (discussed below). We applied a Multicontext model to instructional sequence design in the second year of the program as an intervention to evaluate whether action taken to recognize a broader spectrum of context orientation could positively impact the participating student cohort. Success of this adjustment is defined by measurable advances in student self-efficacy for all program participants. This paper presents a comparison of student survey responses and auxiliary qualitative data from the first and second field seasons (FS1 and FS2, respectively) in order to evaluate how adjustments in instructional sequence design affected student engagement and self-efficacy. Our results suggest that adopting this approach could make a significant positive difference in analogous programs.

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Supplemental data for this article can be accessed at the publisher’s website.

Literature context

The Multicontext theory

Both the challenges of science education in underrepresented communities, and in turn, the low numbers of underrepresented people in STEM fields relate largely to the incompatibility between traditional science cultures and cultures of underrepresented groups (Aikenhead, 1996, 1997; Murray, 1997; Riggs, 1998; Riggs & Semken, 2001; Semken & Morgan, 1997; Wolfe & Riggs, 2017). As the numbers of minority populations grow and scholarship programs for underrepresented groups in geoscience are more available, this cultural dichotomy becomes increasingly apparent. Educational research has shown a continued motivation to find ways to *"make teaching and learning relevant and responsive to the languages, literacies, and cultural practices of students across categories of difference and (in)equality"* (Paris, 2012 p. 93, and references therein), but academic culture is slow to adapt. Hall (1959, 1966, 1976) defined the *cultural context* of people from different backgrounds along a spectrum according to the way they prefer to approach, interpret and perceive information according to family or community influences. The defining characteristics of high (HC) vs. low (LC) context are summarized in Table 1. Academic culture (especially in STEM) favors the "low-context" approach of scientific inquiry as articulated by Weissmann et al. (2019), Ibarra (1999, 2001), and others (Chávez & Longerbeam, 2016; Halverson, 1993), but many students (e.g. women and underrepresented minority populations) bring different cultural values from personal or community-based experiences that tend to be higher-context (Chávez & Longerbeam, 2016; Hall, 1959, 1966, 1976; Ibarra, 2001). Low-context cultures tend to be task-oriented, apply linear thought processes, and compartmentalize information, whereas high-context cultures tend to be process-oriented, think in terms of systems, and value information in a broader context and with integrated topics. Low-context cultures require less social context to interact and interpret the world than high-context cultures (Hall, 1976). Though they are termed "low" and "high," both are equally valued and valid (and complimentary) approaches to understanding and interacting with the world and should not be used to stereotype (Weissmann et al., 2019). Furthermore, Ibarra (2001) recognized that despite an inclination for either end of the context spectrum, individuals often have the flexibility to act across the spectrum situationally or through time.

The Multicontext Theory has broad implications for redefining and expanding diversity and inclusion within the entire *system* of prevailing academic culture in the United States (see Weissmann et al., 2019), but this paper specifically emphasizes the impact of balanced cultural frameworks for teaching effectively at a "classroom level" in the specific academic community of geoscience. Chávez and Longerbeam (2016) described how teaching and learning relationships are embedded in culture and noted methods for teaching on a continuum, from individuated (LC) to integrated (HC) world views, in order to engage the cultural strengths of all learners. To teach with a mixed, Multicontexted framework—one that recognizes, embraces, and *includes* a broader spectrum of "knowing and doing" (Ibarra, 2001; Weissmann et al., 2019)—enriches learning, fosters a sense of belonging (Moore, 2020), provides more equal opportunities for all students to thrive in academia, and creates a more well-rounded and dynamic workforce in STEM.

A note about field education as Multicontexted potential

Many have recognized that field experiences in geoscience are more effective at helping students to understand concepts than classroom-based courses (e.g. Boyle et al., 2007; Feig et al., 2019; Orion & Hofstein, 1994; Riggs et al., 2009; Stokes & Boyle, 2009; Thrift, 1975; Waldron et al., 2016; Whitmeyer et al., 2009) but the measurements of educational benefits are difficult to quantify. Streule and Craig

Table 1. Summary of high context (HC) and low context (LC) cultural values modified from Weissmann et al. (2019), Chávez and Longerbeam (2016), and Ibarra (2001).

Thinking style	
LC	**HC**
Information compartmentalized/possibly separate from context	Information only meaningful when evaluated in context with integrated topics
Examination of isolated ideas valued over real world application	Real world application of knowledge valued over examination of isolated ideas
Linear thinking and analysis	Interconnected (nonlinear) systems thinking and analysis
Interact using direct communication and fact	Interact using indirect communication and embellishment of fact
Task oriented (success evaluated on completion of task)	Process oriented (success evaluated on how well group conducted work)
Time - emphasis on schedules, timelines, deadlines	Time - Time may not fit in a specific schedule; deadlines are flexible
Space - personal property is shared less	Space - personal property is shared more
Teaching style	
LC	**HC**
Individual	Social context
Isolated components and their attributes	Systems, relationships and connections
Less interactive	Interactive
Teacher-oriented	Student-oriented
Theory before application	Application before theory
Multiple choice	Open-ended, place-based
Small to big picture: Understand concept and process first then determine how findings fit into context.	Big to small picture: Understand purpose first; concepts without context are challenging.

Table 2. Context inventory survey results (Halverson, 1993; Supplemental Materials) and corresponding demographic information for students in FS1 and FS2.

	HC/LC	First gen/low income	Native American, Hispanic, Black	Female	Other (LGBTQ, parent status, age)	FS
Student 1	Low	x		x		FS1
Student 2	High	x	x	x	x	FS1
Student 3	High	x	x	x	x	FS1
Student 4	High	x	x	x	x	FS1
Student 5	Low	x			x	FS2
Student 6	High	x	x	x		FS2
Student 7	High	x	x	x		FS2
Student 8	Low		x	x		FS2

(2016) and Kortz et al. (2020) attributed the value of field education in the context of the social framework it provides: one where students develop independent thinking skills, versatility, and self-efficacy. Mogk and Goodwin (2012) posited that it is the immersive nature of learning in the field that allows it to be so effective, and similarly, Elkins and Elkins (2007) suggested the social novelty of the field setting motivates student learning. However, it is important to consider that inaccessibility, unfamiliarity, or unappealing perceptions of fieldwork conditions and logistics introduce barriers for many (O'Connell & Holmes, 2011; Sherman-Morris & Mcneal, 2016). Integration of field-based training, for example, in small liberal arts courses (e.g. Knapp et al., 2006) or Earth science education programs designed for adult learners in Indigenous communities (e.g. Riggs, 2005; Semken & Morgan, 1997), has shown to be broadly impactful when appropriately applied for the student population.

Compton (2016; p. 1) posited that "*field studies are founded on three kinds of information*": (1) Objective data: simple, straightforward facts from direct observation and measurement, (2) Interpretive data: founded on perception and experience, where genetic insight clarifies a host of interrelated data, and (3) Age relations: organizing facts and interpretations into an order of events. Note the symmetry of factual (detailed, operational, observational, literal) and philosophical (interpretive, interrelated, contexted, imaginative) data: A *Multicontext* unity. There is space in the field for students across the spectrum to practice their strengths, and it requires flexibility to adapt to their non-preferred context (high context learners must be meticulous about detailed descriptions and data acquisition; low context learners must be able to interconnect past environments and depositional systems). Field education can be taught with a very low-context approach, but education in the field setting has already presented us with an ideal potential for balanced cultural frameworks in teaching—We just have to activate it.

Study population and setting

Landscapes of Deep Time in the Red Earth of France (NSF International Research Experience for Students) is a four-week, field-based summer program that aims to mentor U.S. undergraduate science students from underserved populations in geological research. Planned as a three-year project, it involves recruitment of a new undergraduate cohort for each season and includes a stipend in addition to full financial support (for travel and living expenses). The program is designed to mentor students in developing basic skillsets (e.g. sedimentologic field techniques and analyses) while being exposed to an interdisciplinary research collaboration and international cultural experience. Initially, recruitment was focused on Native American populations in Oklahoma, but we found local recruitment state-wide to be a challenge owing to the narrow applicant pool and the cultural burden of international travel requiring an extended period of time away from home (e.g. family and tribal obligations). Native American students are the least likely group to attend college or participate in study abroad programs (Field, 2016; Wanger et al., 2012) owing to a desire for support systems that recognize and align values with those of their families and communities (Guillory, 2009; HeavyRunner & DeCelles, 2002). Due to the low response rate from local Native American communities, the recruitment and participation of students expanded nationwide through advertising with the Geoscience Alliance, GeoForce, and other geoscience society forums (e.g. Geological Society of America, American Geophysical Union, NSF Research Experiences for Undergraduate students, Earth Science Women's Network, American Indian Science and Engineering Society). The FS1 and FS2 student cohorts (Table 2; n = 4 per summer, n = 8 total) were composed of undergraduates (rising juniors and seniors) pursuing a B.S. or B.A. in geoscience (or natural resources) where 7/8 were first-generation college students, 7/8 were women, 6/8 were Native American, Hispanic, or African American, and about half were also either nontraditional students in the sense of age, sexual orientation, or parental status. Students originated from a wide range of rural, suburban, and urban communities. According to the cultural context inventory (Halverson, 1993), the majority (5/8) were high-context-preferred, and the others were low-context-preferred (as assessed at the beginning of the field season). Academic ranks varied, but most (6/8) students were rising seniors. Previous backgrounds in relevant coursework, undergraduate research or field experience varied considerably by student (ranging from training at large universities with formal geoscience majors to smaller colleges or tribal schools with integrated environmental programs), and slightly by cohort (with FS2 students being slightly more experienced on average upon entry).

Materials and implementation: Activation of the Multicontext theory

Instructional sequences (Figure 1) were developed prior to two separate four-week field seasons of the IRES program (FS1 and FS2 respectively). The FS1 curriculum was designed with little focus paid to learning philosophies and in retrospect, the pedagogical goals and itinerary

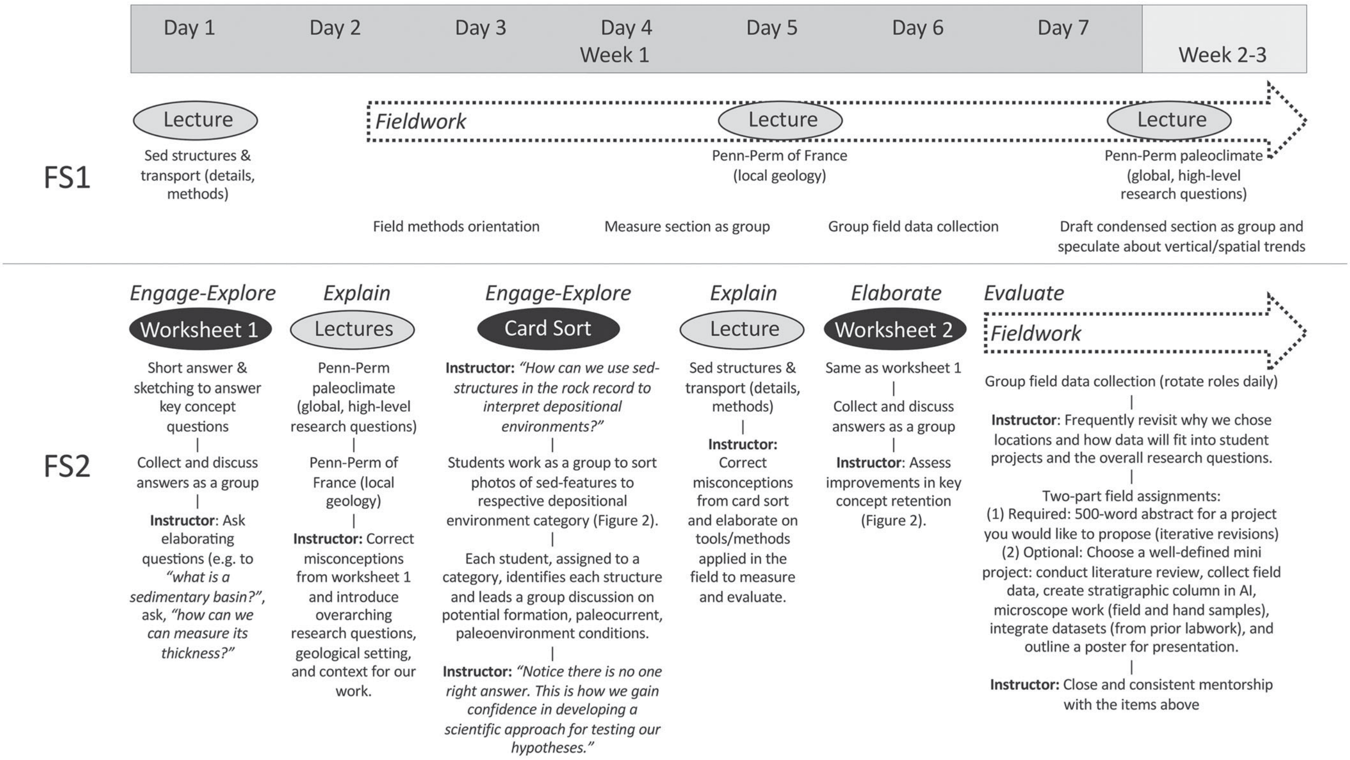

Figure 1. Instructional sequences and corresponding timeline from FS1 (top) and FS2 (bottom).

preferentially served low-context ways of learning and doing. The program orientation was lecture heavy and sequentially ordered from detailed descriptions of field methods to big-picture, contextual talks presented mid-way through the program (after substantial fieldwork). The majority of the field work curriculum for FS1 involved students conducting detailed, unimodal data collection (e.g. measuring stratigraphic section) with linear analysis of the data (e.g. building stratigraphic profiles) and little integration of multiple datasets.

The aim of our program (structured according to NSF IRES objectives) is twofold—Aside from the education and pedagogy aspect (to attract underrepresented students to STEM), there is a significant component of conducting geological research and collecting new and publishable data to answer questions about ancient climates. Given that (1) our fieldwork takes place internationally with complicated logistics and limited resources, (2) aside from teaching, we had to acquire a large amount of data in a brief time, and (3) our student cohorts did not belong to any one underrepresented demographic (Table 2), it was not possible to adjust the FS2 curriculum design to include elements proven effective for specific cultures (e.g. for Indigenous populations: place-based curricula in traditional homelands, integration of Indigenous knowledge, explicit involvement of Indigenous leaders/educators; Johnson et al., 2014; Murray, 1997; Riggs, 2005; Riggs & Semken, 2001; Semken & Morgan, 1997; Semken, 2005; Semken et al., 2017; Unsworth et al., 2012; Wildcat, 2018). Instead, we focused on a strategy to recognize and include a broad spectrum of culturally-based learning approaches. Guidance for building a Multicontextual classroom (Chávez & Longerbeam, 2016; Ibarra, 2001; Weissmann et al., 2019; Table 1) heavily influenced the revision of the instructional sequence from FS1 to FS2.

The framework for the FS2 instructional sequence (Figure 1) started with a one-week mixed lecture and application orientation structured according to the BSCS (Biological Science Curriculum Study) 5E Instructional Model (Bybee et al., 2006; Bybee & Landes, 1990). Our decision to rely on the framework of the 5E *learning-cycle* approach for FS2 is grounded in theoretical foundations which veer from traditional teaching methodologies and emphasize the development and application of student-centered lessons (Abraham, 1997; Duran & Duran, 2004). While traditional pedagogical approaches stress the progression of skills toward a pre-determined outcome, learning cycles are based on "constructivist-learning"—emphasizing the investigation of phenomena and use of evidence to support conclusions (Abraham, 1997; Duran & Duran, 2004). There are more opportunities in the 5E learning cycle approach for students to self-reflect, redefine and elaborate, and interact with peers to solve problems (Bybee, 1997). It is more of a non-linear systems approach that holds a greater emphasis on integrated ideas and applications: A traditionally high-context cultural value. The 5E Model consists of five stages (Engage, Explore, Explain, Elaborate, and Evaluate) in which students formulate a better understanding of scientific processes and skills based on first-hand experiences (Açışlı et al., 2011; Newby, 2004). The *Engage* phase is meant for the instructor to assess and connect to prior knowledge and introduce a new concept through the use of short activities that stimulate curiosity. In *Explore*, a common experience is provided so that the students can apply prior knowledge to generate new ideas

Figure 2. Photos display examples of elements implemented in FS2. *Top right:* Pre-to-post field season improvements in Pangea sketches from the Engage-Elaborate phases of 5E orientation. *Bottom right:* A card sort activity *"how can we use sedimentary structures in the rock record to interpret depositional environments?"* in the Explore-Explain phases of 5E orientation. *Left:* Examples of students using equipment in the field (Gigapan outcrop imaging) and at home (DinoLite microscope) to pursue individual projects.

and begin investigation. In the *Explanation* phase, students are given the opportunity to demonstrate their conceptual understanding and the instructor corrects misconceptions before moving onto *Elaboration* wherein students have an opportunity to apply their understanding of the concept to a different situation or activity. Finally, in *Evaluate,* students are encouraged to assess their understanding and abilities to complete a final exercise or activity that allows the instructor to evaluate student progress overall. Figures 1 and 2 detail specific lectures and activities included in each of the 5E steps for FS2 orientation. This model provides shared experiences (e.g. workbooks with exercises to compliment lectures, card-sort activities, sketching, journaling) that place application before theory (HC-preferred; Table 1). Lectures are ordered from overarching research questions to basic concepts and field skills (opposite of FS1, as requested in FS1 student feedback; Table 5) and are completed before the start of work in the field. This way, students gain awareness of relevant background knowledge and major research questions *prior* to beginning field work, enabling all *new* data and information—first-hand experiences in the field—to be evaluated in a broader context (HC-preferred; Table 1).

After the 5E-structured orientation, it is important to continue integration of the Multicontext model in field pedagogy. Skills and concepts taught in the field are coupled with discussion (and frequent review) to specify the contribution of the process or data to the overarching research questions. For example, "we are doing this [low-context activity] today, but with integration of [other datasets] it relates to the broader context by addressing [this primary research question]." This way, data collection—which tends to be repetitive, detailed, low-context work—is *able* to be perceived in a more process-oriented, relevant, and interconnected way (HC-preferred; Table 1). Furthermore, additional equipment (e.g. Gigapan for outcrop imaging and lithostratigraphic correlation, portable DinoLite microscope for hand sample and thin section analysis, drafting software; Figure 2) and data from FS1 (e.g. thin sections, geochemical data) are available for students to pursue an *optional* predefined individual "mini-project." This added an element to FS2 for students to interpret and integrate multiple data sets (e.g. stratigraphy and magnetic susceptibility), opening doors for systems thinking and analysis (HC-preferred; Table 1).

Evaluation

Students did not receive course credit or grades for their participation in the IRES program, so while exam performance is the quantitative standard for evaluating student success in academic environments, here we focus on the quantitative measurement of gains in student self-confidence through exposure to the change in curriculum from FS1 to FS2. The social cognitive theory investigates how perceived self-efficacy affects human action and thought. From Bandura (1986, p. 367–368*): "Self-efficacy scales do not measure skill; they measure what people believe they can do under varied circumstances, whatever skills they possess, or the particular skills required by the task… Judgements of operative self-efficacy are concerned not with the skills one has, but with beliefs about what one can do with the sub skills one possesses in dealing with continuously changing realities, most of which contain ambiguous, unpredictable, and stressful elements."*

Student participants each summer (FS1 and FS2) completed identical surveys that served as pre and post measures of self-efficacy and a culminating attitudinal survey to evaluate the quality of the overall program. The questions and structure did not change between FS1 to FS2. The surveys were developed by the authors prior to the first field season and were administered by the same instructor on the

Table 3. Raw data from pre-post and attitudinal assessments (Supplemental Materials). Questions from each survey are provided at the bottom of the table. Total Pre and Total Post is the score total per student for the whole assessment. The score for each question on the pre-post assessment is between 1 and 3 where 1 indicates highest confidence (1= yes, I understand this sufficiently so that I can do or explain this independently, 2= I can follow this in class or when I have an example but am confused when I work on my own, and 3= I recognize what this is referring to, but I don't understand or know how to do it). The score for each question on the attitudinal survey (comprehensive program evaluation) is between 0 and 3 where 3 indicates the highest rating (3= Excellent/very satisfied, 2= Very good/satisfied, 1= Average/neutral, and 0= Below average/dissatisfied).

			Pre-Post self-rated assessment			Attitudinal Survey
Student ID	Year	Context	Total Pre	Total Post	Gains (Pre-Post)	Total Score
Student 1	FS1	High	27	16	11	25
Student 2	FS1	Low	23	13	10	26
Student 3	FS1	High	19	12	7	25
Student 4	FS1	High	16	20	−4	28
Student 5	FS2	High	27	13	14	30
Student 6	FS2	Low	15	12	3	30
Student 7	FS2	High	22	12	10	28
Student 8	FS2	Low	21	12	9	23

Pre-Post self-rated assessment questions *(n = 12)*	Attitudinal survey questions: Program evaluation *(n = 10)*
Defining what a sedimentary basin is and why we're interested in studying one.	This international REU program was well organized as a whole.
Understanding of what the continents looked like 250 million years ago.	The international component of program added value to scientific experience.
Understanding of global icehouse vs. greenhouse paleoclimate conditions.	I would recommend this program to others.
Ability to use a Jacob's staff to measure and record a stratigraphic section.	I would recommend my mentor(s) for future projects.
Ability to thoroughly describe and identify sedimentary rocks in outcrop.	The value of your project to your future graduate school or professional career.
Ability to identify sed structures in outcrop and hypothesize about formation.	Information presented during orientation (workbooks, evening lecture series).
Understanding/IDing sediment transport mechanisms + associated structures.	The program in providing a broader view of what geoscience is.
Ability to hypothesize about sed transport/depositional environs based on obs.	The program in providing you with skillsets that make you more confident in field.
Confidence in formulating several hypotheses based on observations.	The program in helping you understand uncertainty and interpretation in science.
Confidence in developing a methodical scientific approach to testing hypotheses.	Your acceptance into the research group as a contributing member.
Ability to integrate mult. datasets to make well-supported interpretations.	
Conducting independent geological fieldwork.	

mornings of the first and last days of the program. No time limit was enforced for completing the survey; with both the survey questions and follow-up short answer questions, the typical student took about one hour to complete the survey. The identical pre and post survey includes ∼12 items (Table 3) designed to measure development of self-efficacy in research applications and content knowledge (e.g. understanding of past climates, sedimentological skillsets). For each item, students self-rank their level of confidence (1–3 from highest to lowest) in each concept or skill. The attitudinal survey—taken only at the conclusion of each field season (at the same time as the post-survey above)—asks students to rate ∼10 aspects of the program on a scale 0–3 from lowest to highest quality (Table 3). Quantitative data from surveys (Table 3) were analyzed in R Studio using paired t-tests, and t-tests to assess differences between two populations (Table 4).

In addition to the surveys described above, qualitative data sources include (1) instructor logs from informal, weekly reflections (group share) and (2) short-answer responses at the end of pre- and post-surveys (described above). The informal, weekly reflections were held as a group (all students and mentors) and were meant to encourage self-reflection and career development discussion. The students were asked to reflect on their experience weekly through journaling, but sharing was optional. Participant responses during informal reflections were transcribed by the instructor and unitized into unique data pieces. A constant comparative approach (Glaser, 1965) was used to identify key themes in areas of program improvement (from a student perspective). Select data units that exemplified this theme are summarized in Table 5 for each field season. Each (pre- and post-survey) includes six short answer questions: Most are intended to obtain background (e.g., coursework or motivation to participate in the program) or general career goal (e.g., intent to apply to grad school) information. However, two of the open-ended questions prompted responses from the FS2-student cohort that were characteristic in nature according to their context inventory (selected for summary in Table 6). Students in FS2 took the cultural context inventory survey (Halverson, 1993) at the beginning of the season to document preferred context and associated work ethic/learning behaviors, and students in FS1 were asked to complete it retroactively. All survey instruments are accessible in the Supplemental Materials.

Results

Student participants in the NSF IRES program are from racial/ethnic minority groups, low socioeconomic status, and/or are nontraditional students, and are primarily high context-preferred learners (Table 2). In the final attitudinal survey (Table 3), students rated the overall quality of the program higher in FS2 (mean 28) than in FS1 (mean 26).

Table 4. Summary of pre-post self-rated assessment (Supplemental Materials) statistical analysis. Shaded cells indicate where gains are statistically significant.

		Year	Context	Total Pre	Total Post	Gains (Pre-Post)		P-value*
a	Mean *(n = 8)*	All	All	21.3	13.8	7.5		< 0.01
b	Mean *(n = 5)*	All	High	22.2	14.6	7.6		0.07
c	Mean *(n = 3)*	All	Low	19.7	12.3	7.3		0.08
	Signif. of gains FS1 to FS2						Difference	P-value**
d	Mean *(n = 4)*	FS1	All	21.3	15.3	6.0		
e	Mean *(n = 4)*	FS2	All	21.3	12.3	9.0	3.0	0.50
	Signif. of gains FS1 to FS2, HC vs. LC						Difference	P-value**
f	Mean *(n = 3)*	FS1	High	20.7	16.0	4.7		
g	Mean *(n = 2)*	FS2	High	24.5	12.5	12.0	7.3	0.24
h	Single *(n = 1)*	FS1	Low	23.0	13.0	10.0		
i	Mean *(n = 2)*	FS2	Low	18.0	12.0	6.0	−4.0	N/A

*using paired t-test.
**using t-test.

Table 5. Select student feedback from informal weekly reflections. These statements represent key themes regarding areas of improvement from a student perspective (by field season).

FS1	FS2
Evening lectures were a valuable part of the learning experience, but I wish they were given in reverse order.	*Mini lectures every so often IN the field (e.g. map-reading) would be helpful.*
Assigned readings of overview papers would've been helpful to prepare for the field season.	*The onboarding series and order of lectures provided a good foundation prior to field work.*
Big picture lectures would've provided a better foundation before fieldwork.	

Findings from the pre-to-post self-rated assessments suggest that student participation in the program, regardless of year or cultural context, resulted in advancement of student confidence in research application, independent field work, and their ability to contribute to science (Table 3; all but one student show positive gains from the beginning to end of the field season). As shown in Table 4*a*, this overall positive gain in pre-to-post survey scores (mean +7.5) for all students ($n = 8$) both years, is statistically significant ($p \ll 0.05$). Within this group, HC ($n = 5$) and LC ($n = 3$) students each improved (∼+7.0; Table 4*b-c*) by insignificant ($p = 0.07$–0.08) gains, but there is no statistical difference ($p = 0.94$) in the mean gain between context groups overall.

Establishing significance is not possible with analysis by distinct year *and* context orientation due to small sample sizes, but the improvements are still quantitatively measurable. For example, the pre-to-post difference in mean scores (+3.0) for all students from FS1 ($n = 4$) to FS2 ($n = 4$) indicates self-rated improvement overall in FS2, though not by a statistically significant margin ($p = 0.50$; Table 4*d-e*). However, if we isolate the data to examine only those students who tested as high context, the increase in mean pre-to-post-survey gains (+7.3) from FS1 ($n = 3$) to FS2 ($n = 2$) is closer to being statistically significant ($p = 0.24$; Table 4*f-g*), but not quite due to the small numbers of students. In contrast, students who tested as low context at the beginning of the field season saw a minor decline in mean pre-to-post gains (−4.0) from FS1 ($n = 1$) to FS2 ($n = 2$), but it is not possible to assess significance with only one student in FS1 (Table 4*h-i*).

Key themes in qualitative data are identified and reported in Tables 5 and 6. Table 5 summarizes areas for program improvement (from a student perspective) that influenced changes in instructional sequence design for each subsequent field season. Table 6 summarizes open-ended responses (from FS2 only) to select questions from the pre- and post-survey that demonstrate the expected nature of student participants as predicted by their context inventory.

Discussion

The Multicontext Theory does not suggest that one way of knowing and doing (high or low context) is better than the other. However, because academia (and especially STEM) traditionally favors low context approaches, the objective for FS2 was to integrate more aspects into the instructional design that are typically high-context-favorable (see Table 1), especially given the demographic of the students in the program. We consider that the overall success of the program is defined by the ability to have *all* participating students improve by quantifiable (pre-to-post survey) margins *and* to observe qualitative behaviors that demonstrate a connection and engagement to the work. In this discussion, we will first review components of the FS2 Multicontext model, and the data (quantitative and qualitative) that largely support its positive impact. Then we will assess other factors that possibly contributed to the change in student experience from FS1 to FS2.

Student participation in the program *in general* results in measurable and significant advances in student self-efficacy (Table 4*a*), but to assess the impact of Multicontext activation in curriculum design in FS2 (with the particular objective of being more inclusive of higher-context modes), we must analyze the results by year and by preferred context orientation. From FS1 to FS2 we see an increase in the pre-to-post survey margin (+3.0; Table 4*d-e*) of self-assessed student confidence (e.g. in relevant skills/competencies, research application, independent field work, scientific thinking) and in the student-rated overall quality of the program. Despite the inability to determine statistical significance due to small sample size, substantial gains in student self-efficacy from FS1 to FS2 were reported by higher-

Table 6. Open-ended survey responses from select questions on the pre-and post-assessments (Supplemental Materials) by context inventory (FS2 only).

"What are your goals?" (pre-assessment) vs. "Were your goals accomplished?" (post-assessment)		
	Pre-Assessment	*Post-Assessment*
High	I want to become more prepared for my future career	Yes, I made a poster outline and learned about fieldwork in geology
High	Learn how to conduct paleoclimate research and field research skills	Yes, I learned how to complete geological fieldwork and use different techniques in formulating hypotheses and how to test them.
Low	I would like to learn more about the methodology of paleoclimatology to help decide between that and paleoecology	Yes, fully.
Low	I'd like to have a good experience in field research and interpretation so that I know what to expect in the future and feel comfortable to conduct fieldwork independently.	Yes, my main goal was to have a real research experience - field work, discussion, interpretation, written product. I am looking forward to continued work on my mini project at home and eventually presenting.
"What do you like about science (e.g. fieldwork/research/sedimentology/paleoclimate)?" and "How would you rate your ability to think scientifically/work independent research projects?" (pre vs. post assessments)		
	Pre-Assessment	*Post-Assessment*
High	I think I understand research well and can think independently	I like the mystery and problem solving. I would rate my abilities at adequate but needs improvement.
High	I love that science is very methodological and the concepts are concrete but it can also be examined and reshaped. I love the interdisciplinary nature of science.	I had a great time doing fieldwork. I would rate my ability at a 8/10
Low	I adore learning new things and science is the best way to do that; I am not sure how good I am, but I do work alone often.	I enjoy learning new things in a scientific process and in sed/ paleoclimate I can understand the history of earth was like at the time. I would note that my ability to work independently is high.
Low	I like being able to interpret what happened in the past and then apply it to the future. I would say that I can think scientifically and work well independently.	I look at science as a "healthy challenge"—I can think very well scientifically and ask good questions. I am excited to pursue a small independent research project with guidance.

context students (+7.3; Table 4*f-g*) while lower-context students reported a slight decline (−4.0; Table 4*h-i*). Based on these data and observations, we interpret that FS1 was more supportive of low-context students, and that activation of a Multicontext approach in FS2 (Figure 1) resulted in a more inclusive environment, especially for higher-context students.

Observationally, there was a stark contrast between FS1 and FS2 in individual student level of focus and engagement through the field season. FS1 student feedback (Table 5) suggested a lack of clarity around how their work fit into the broader research questions. It is likely that instruction of content and skills without a broader context (e.g. how/where data collected in the field would eventually be applied) resulted in a potentially challenging and unsupportive learning environment, especially for higher-context students. Balancing across cultural frameworks (Chávez & Longerbeam, 2016; Weissmann et al., 2019) in the instructional design for FS2 (Figure 1) resulted in improved student engagement. Defining research objectives *early* (week one pre-field 5E-structured orientation) and revisiting them often (discussing *how* data collected throughout the field season fits into broader research questions) resulted in a strong understanding of the purpose of the research before beginning work in the field. During the 5E orientation, high-context students were particularly animated and tended to lead the group in activities like the card sort (Figure 2), not just because it was "active" but because it involved systems thinking about how detailed observations (sedimentary structures) were produced in different systems (depositional environments) and speculation about contextually significant implications (regional climate). For example, while lower-context students focused on assigning the correct name and paleocurrent direction to each feature, higher-context students would ask questions like: "*Why can't this feature belong to both fluvial and glacial systems?*" and "*Why can't this feature indicate paleoflow going in multiple different directions?*" The answer to both being that they can! It is a perfect example of how in science there is "no one right answer"— but there is also no single "right" way of *thinking*. It is hard to determine how the prevailing role of higher-context students in these scenarios impacted the learning environment for lower-context students: But it did seem to positively influence lower-context students to consider alternative solutions (usually further outside of the textbook definitions). The option to have ownership of individual projects/ products, access to equipment, and continued mentorship associated with evening (after-field) work also fostered a better overall student connection to the research in FS2 by allowing them to take direction in their learning experience.

Survey responses from FS2 (Table 6) characterize the typical or expected nature of student behavior as predicted by their context inventory. Lower-context students were very goal-specific and product-focused—almost disappointed if they did not fully complete the assembly of a poster presentation during their time (Table 6; row 4, 8, col 2)—whereas higher-context students had intentions to absorb diversified aspects of the entire system (and consider all the data) rather than being limited to an individual project. Lower-context students excelled at data collection, drawing upon an inherent inclination to metrics and detail, whereas higher-context students struggled to maintain focus during these activities, but asked relevant and impactful questions such as "*Why did we choose this locality?*" and "*What does this feature mean about the climate at the time of deposition?*" Questions, group discussions, and student-lead initiatives to conduct literature reviews and practice petrography skills (with the DinoLite microscope) showed a level of interest and engagement in and out of the field that was not apparent in FS1. The quality and quantity of work produced by students during FS2 was impressive. Three students (a mix of higher- and lower-context) continued work on individual research projects after their return from the field program and have presented at undergraduate research symposia (at their home institutions) as well as at Geological Society of America conferences (Birkett et al., 2020; Mueller et al., 2020).

The development of a positive or negative team chemistry was also a driving element in the overall learning experience in regard to student level of focus and engagement. It is possible that activation of a Multicontext approach reduced competition and individuation, cultivating a more integrated student cohort in FS2. On the other hand, an initially more cohesive cohort in FS2 could have also contributed to the margin of improvement over FS1 (effectively minimizing the importance of the change in instructional approach). In FS1, an abrupt shift from excitement and euphoria to arguments and alienation among student participants occurred in the second week. This shift, known as "forming" to "storming" according to Tuckman's small group dynamics hypothesis (Tuckman, 1965, Tuckman & Jensen, 1977), negatively impacted the learning environment and contributed to a degradation in student engagement despite its intangibility. Integration and discussion of personality assessment data (Myers-Briggs; Briggs, 1987) at the beginning of the field season, coupled with a more naturally-cohesive cohort, generally resulted in a more positive team dynamic and sustained engagement. The personality assessment included a brief discussion on context orientation, but it would be interesting to elaborate on cultural context and the Multicontext model at the beginning of FS3 to see if there is an influence on group dynamic with improved comprehension of self and teammate tendencies in respect to the cultural context spectrum. With work like this that involves small-group collaboration in a field context where different personalities are forced to work closely and interact both in a working *and* living space, we can expect that student focus and engagement will be affected in part by team chemistry and dynamic.

Additional factors that potentially influence the improvement from FS1 to FS2 include: (1) the varied academic background of students upon entering the program. However, the FS2 cohort had more previous experience in geoscience-specific courses and experiences, so this is likely *not* a driving factor, as we would expect to see *smaller* pre-to-post assessment gains in FS2 than in FS1. Also, note that the mean total self-assessed pre-score for FS1 and FS2 match (Table 4*d-e*). (2) Another factor could be adaptability (e.g. culturally or intense fieldwork) that was covert. These aspects could have varied with time—by individual or by group—and may have influenced some assessment responses as well. Finally, (3) as noted above, the field setting is inherently underlain by Multicontexted potential.

Limitations

Some of the most valued intentions of this experience are inherently difficult to measure (e.g., improved understanding of the scientific process, a stimulated passion to pursue a STEM career, student interest/engagement), especially with the limitations of a particularly small and diverse sample size (four students annually). A more robust sample set in terms of number of students and number of survey questions may have changed or enhanced the significance of results. Additionally, several variables are difficult to control (e.g. the impact of small group dynamic, changes in the applicant pool or recruitment/selection procedures, varying levels of prior experience by student). Finally, the data are acquired through means of self-reporting so it is subjective, and we are limited to discussion about improvements in self-efficacy. To obtain a more direct read of student skill acquisition or concept retention, an objective method of measurement is required (e.g. formal exams or demonstrations in the field), but likely not possible for this program given the lack of formal grading or option to obtain coursework credit. All of these potential limitations should be considered in the interpretation of results and in planning for the final field season (FS3).

Implications and future study

This study is only one example of how a short field-based program like IRES can benefit from a broadened spectrum of context teaching frameworks. Future plans include continued implementation of the Multicontext model for the final season of the NSF IRES program (FS3) to assess whether results are reproducible with a different group and/or location. Pre- and post-survey formats will be preserved to keep data comparable between successive field seasons. Changes will include expanding on the informal reflections, lunch discussions, and integration of "mini lectures" into the field day. The integration of mini in-field lectures for brief skillset review (e.g. map-reading) is based on FS2 student feedback (Table 5) and serves as an opportunity to continue tying the selection of field locations and data collection plans back to broader context research questions (as discussed in FS2). Students in FS3 will complete the same context inventory survey (Halverson, 1993), as well as a more comprehensive scaled Context Diversity matrix developed by Ibarra *(pers. commun. 2019)*. An introduction to the Multicontext Theory will be shared with the students at the beginning of the field season so they can begin to recognize when they are engaged in higher- or lower-contexted work. We are interested to (1) test which (if either) of the context inventory tests is more insightful, and (2) observe the fluidity of student context orientation over the four-week timeframe. We expect that if the students have some awareness of the Multicontext model, and where tasks fit on the spectrum, we will observe shifts over the course of the field season in their context-inventory results, indicating their adaptability to use both perspectives in comprehension and application.

Conclusions

Programs (like NSF IRES) that support undergraduate students from historically underrepresented groups in international STEM research might find more success in student engagement when leaders and instructors recognize and activate the Multicontexted culture of their research group. With heavy (international) travel logistics, a different student cohort each year, and a relatively short field season, it is challenging to assess context orientation, manage interpersonal group dynamics, and provide students a meaningful educational experience that is well-balanced with productive data collection. We found it important to fuze typical (by definition) "high" and "low" (integrated and individuated) context teaching frameworks because students may shift higher or lower on the spectrum situationally or through time, and the ultimate goal is to create *Multi*contextual thinkers (both low and high context are equally as important, but the full spectrum must be valued).

Separate cohorts for the first two years of our program are mostly first-generation college students from historically underrepresented groups in STEM, and most are "high context"-preferred learners. From FS1 to FS2, there are measurable improvements in student self-efficacy overall (e.g. in concept comprehension, field/analytical competencies, research application), but they are dominantly reported by high-context students. Associated with these quantitative (survey-derived) gains, observational transformations into FS2 include a higher quality of work, and a positive, productive and integrated group dynamic that we interpret to reflect higher levels of student engagement and inclusion as scientists. These improvements (quantitative and qualitative) can be attributed partially to the shift from an FS1 low context-preferred instructional framework to a more balanced, Multicontexted culture in FS2. The FS2 instructional sequence includes (1) a mixed lecture-application 5E-structured orientation prior to fieldwork that clearly introduces the broad research objectives early, (2) frequent discussions during fieldwork to place low-context tasks in a broader context (e.g. explain how the current dataset will be integrated with other information and ultimately impact major research questions) and (3) a pre-defined mini-project *option* that allowed students to set an individual intent for growth in this experience (e.g. integrating multiple datasets to focus on a single idea vs. applying diversified field methods to contribute to several ideas). Weissmann et al. (2019, p. 7) stated that *"activation of the Multicontexted approach requires systemic, institutional cultural change by broadening values to be inclusive of high contexted approaches."* Within the Multicontext *system*—a theory that has broad implications for the entirety of academic culture—this study represents a small segment of how *awareness* of the Multicontext Theory as an instructor, coupled with relatively minor adjustments to balance across cultural frameworks in teaching, results in a more inclusive environment for students to apply their individual strengths and cultural context to effect an enhanced learning experience.

Acknowledgements

NSF IRES student participants (2018 and 2019). M. Powell for review and assistance with statistical analysis. Thank you to our reviewers (A. Aitken, M. Moore, M. Powell, and others) and editors at JGE for their assistance improving this work. University of Oklahoma Office of Human Research Participant Protection/Institutional Review Board (IRB No. 9330).

Funding

This work was supported by the National Science Foundation under International Research Experiences for Students (IRES) grant No. 1658614 (G.S. Soreghan, M.J. Soreghan) and National Science Foundation grant No. 1338331 (G.S. Soreghan). Additional support was provided by the Eberly Family Chair in Geosciences at the University of Oklahoma (G.S. Soreghan).

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