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| Research Article

Student perceptions of inclusive pedagogy in undergraduate STEM classrooms

Caley J. Valdez,[1] **Nicole C. Kelp**[1]

AUTHOR AFFILIATION See affiliation list on p. 10.

ABSTRACT In university STEM classrooms, the incorporation of inclusive practices improves student performance, decreases disparities in the academic success of underrepresented students, and increases student retention and persistence in Science, Technology, Engineering, and Mathematics (STEM) programs. Inclusive pedagogical practices include effective instructional choices like active learning, providing rubrics, and other strategies that have been shown to support students from disadvantaged backgrounds. Additionally, explicitly inclusive practices such as addressing microaggressions and sharing pronouns can promote a sense of belonging for students. While a plethora of literature has shown these impacts and faculty have access to resources and training about inclusive pedagogy, we were interested in whether students are noticing these practices and how student identities impact their observations of instructional practices. We surveyed undergraduates (n = 74) from diverse STEM disciplines at a large land-grant university regarding their observation of 11 different inclusive pedagogical practices. Overall, students observed inclusive instructional practices more often than they observed explicitly diversity, equity, and inclusion (DEI)-related practices. For explicitly DEI-related practices, white students observed more practices than Students of Color. This suggests that more work needs to be done to train faculty in explicit DEI-related practices, especially with the goal of supporting Students of Color who have been historically excluded from STEM.

KEYWORDS inclusive pedagogy, science identity, science self-efficacy, self esteem, STEM

In university STEM classrooms, inclusive pedagogy improves student performance, decreases disparities in the academic success of underrepresented students, and increases student retention and persistence in STEM programs (1–4). Additionally, student affective measures (SAMs) such as science identity impact retention, belonging, and success in STEM (5). In this study, we utilize a survey of undergraduate STEM students at a large land-grant university to examine the relationship between their perceptions of inclusive pedagogy, their personal identities, and their affective measures. We aimed to examine how students' lived experiences in STEM classrooms may influence their perceptions and development as scientists.

Types of inclusive pedagogy

Inclusive pedagogy can manifest in multiple ways, including instructional practices that close opportunity gaps as well as the use of inclusive language in the classroom and, more broadly, the promotion of diversity, equity, and inclusion (DEI).

One of the mechanisms behind why instructional practices such as active learning strategies and providing adequate structure for coursework are so crucial for inclusivity is that they do not require students to rely on social background in order to succeed in the college classroom (6). The Community Cultural Wealth Model is a framework used

Editor Sarah Fankhauser, Emory University, Atlanta, Georgia, USA

Address correspondence to Nicole C. Kelp, nicole.kelp@colostate.edu.

The authors declare no conflict of interest.

See the funding table on p. 10.

Received 19 June 2023
Accepted 14 September 2023
Published 24 October 2023

to understand educational inequalities; it describes how students navigate academia depending on six forms of capital: aspirational, linguistic, familial, social, navigational, and resistance (6). Students with varying identities–marginalized or privileged–have differing experiences and differing degrees of access to these forms of capital (7). This has been demonstrated in first-generation students, Students of Color, and numerous other underrepresented populations (7, 8). Students of these historically marginalized backgrounds are rich in cultural wealth that enables them to succeed in the college classroom regardless of social privileges or academic background.

In addition to instructional practices that provide inclusive access, explicit DEI-related practices include instructors discussing intentions for inclusivity in class, ensuring sources come from a variety of diverse voices, and disclosing their own experiences with inclusivity and identity (9–11). Use of these practices in the classroom has been shown to improve perseverance in STEM programs and increase commitment to STEM careers for undergraduate STEM students, particularly in Students of Color (2). This pedagogy combined with incorporating traditional Indigenous environmental knowledge into STEM courses specifically improves the retention and performance of Native American and Indigenous students (12). Unfortunately, there is also evidence that environments without inclusivity are hostile to students with marginalized identities by creating additional emotional labor requirements, putting up barriers to academic achievement, and causing lasting mental and emotional strain (13). Unsurprisingly, this has been shown to be uniquely harmful to Students of Color (13). All students who show desire and effort to pursue STEM should be able to remain in these programs unless they find a new passion; institutional barriers pushing students of numerous identities and backgrounds out have undeniably been a great loss to science and related fields.

While multiple studies have examined the importance of inclusive pedagogy, fewer studies have explicitly examined how students perceive inclusive pedagogical practices. This led us to develop the following research question:

RQ1: What inclusive practices do students observe in STEM classrooms and at what frequency, and how do student identities impact these observations?

Student affective measures that impact success in STEM

SAMs like science identity, science self-efficacy, and self-esteem can impact student success in STEM. Science identity is defined as a student affective measure that "…not only involves whether an individual wants to become a 'science type person,' but also as the socialization of individuals into the norms and discourse practices of science" (14, 15). In STEM students, one's sense of science identity has been demonstrated to be predictive of science success and improve retention, sense of belonging, and performance in STEM coursework (16, 17). Even in younger K-12 environments, science identity is a driver of academic decision-making, markedly for young girls (15). When combined with science communication skills, science identity was improved and also positively correlated with intention to pursue careers in biomedical research in students of a variety of identities and backgrounds (18). While many factors can influence science identity, one driver has been shown to be a sense of community and affiliation (15, 19). Since inclusive pedagogy can build that sense of community in a classroom (20), it is likely that inclusive pedagogy could support students' development of science identity.

Science self-efficacy is another student affective measure that is a strong predictor of achievement in students of many identities (21). Science self-efficacy can be defined as "a person's belief in the ability to successfully complete specific tasks in the field of science" (22, 23). When combined with active learning strategies in undergraduate science classes, stronger self-efficacy significantly increased academic performance–this was found to be especially true of underrepresented student populations (11). Even in non-STEM university students, self-efficacy has been shown to improve biological literacy (24). Additionally, in minority student populations, improving science self-efficacy bolsters interest in science careers after college (25). Science self-efficacy seems to fulfill and motivate students largely in the same way that science identity does.

Self-efficacy can be developed when students have opportunities to practice science skills (17); as such, participating in an inclusive classroom with structure, active learning, collaboration, and examples of effective work could increase students' sense of science self-efficacy.

Finally, self-esteem also positively associates in students (STEM or non-STEM) with academic performance across a variety of immigrant/non-immigrant and racial and ethnic groups (26). This trend seemed to be stronger in Students of Color who were also immigrants (26). Unfortunately, the perception of a hostile environment and sensitivity to gender rejection for female STEM students at the university level were correlated with decreased self-esteem (27). Inclusive classroom environments have been shown to increase self-esteem for certain students, such as those with disabilities (28), and this should be further explored in undergraduate STEM classrooms.

Both inclusive pedagogy and these SAMs are correlated with STEM student success. Based on literature showing that the results of an inclusive classroom–such as sense of community and achievement–can increase these SAMs, we wanted to examine how student observations of inclusive pedagogy may influence these SAMs.

RQ2: How does students' observing of inclusive practices influence their affective measures of science identity, science self-efficacy, and self-esteem, and how do student identities impact these relationships?

METHODS

Survey development

We developed a survey utilizing university resources and literature to develop a list of inclusive instructional practices as well as explicitly DEI-related practices and validated scales for SAMs (Table 1). For the types of inclusive pedagogy, we did not generate an exhaustive list but identified several practices from the literature [e.g., the PULSE Diversity Equity and Inclusion rubric (29)], as listed in Table 1. We designed a bidirectional scale to ask about the frequency of inclusive practices STEM students were witnessing in their STEM courses (Fig. 1). We sought to survey STEM students who had completed at least one semester at our institution, to ensure that our survey participants had multiple instructors over the course of multiple semesters. Thus, a traditional Likert scale did not seem to adequately grasp the breadth of students' experiences. We analyzed this data either as nominal/categorical selections to enable statistical tests such as chi-square, ordinal values to enable statistical tests such as *t*-tests and linear regressions, or via a bidirectional axis to enable data visualization. Additionally, the survey included validated scales for science identity (5), science self-efficacy (5), and self-esteem (30) and also a section to ask students for their demographic information and identities, in order to compare similarities or differences between various groups.

In addition to the validity derived from the literature, we were also interested in the validity derived from member reviews. The literature has identified that students are aware of and able to identify issues like microaggressions and how they are addressed or not addressed (33–35). Additionally, we performed three think-aloud/ cognitive interviews (36) with undergraduate STEM students to ensure that they were interpreting the items we generated on our survey in the same way we as researchers were. All three students interpreted our questions about inclusive pedagogical practices and bidirectional scale in the same way that we intended. Some students showed a particular understanding and consideration of inclusive pedagogy. For example, two of three students discussed how instructors addressing microaggressions in the classroom demonstrated the instructor's commitment to inclusive pedagogy throughout the semester, not just on the syllabus, and helped to maintain a safe space in the classroom. Students did note that some survey items were slightly wordy and took a minute to comprehend, but ultimately the items were understandable. Some students pointed out that phrases like "adequate instruction" may have individual interpretations, but this does not reduce the validity of students' individual responses on whether instructions are adequate for them. One student mentioned that the impact of instructors' inclusive

TABLE 1 Survey items

Construct	Items	References
Inclusive instructional practices	How often do you observe your STEM instructors providing opportunities for students to interact with each other and build a sense of collaboration in class?	(1, 3, 9, 11)
	How often do you observe your STEM instructors using providing adequate structure for activities and discussions in class?	(1, 3, 9, 11)
	How often do you observe your STEM instructors providing adequate structure for homework and other assignments?	(1, 3, 9, 11)
	How often do you observe your STEM instructors providing examples of completed work (homework assignments, papers, presentation slides, lab reports, etc.)?	(1, 3, 9, 11)
	How often do you observe your STEM instructors providing rubrics for homework, papers, or other assignments?	(1, 3, 9, 11)
Explicitly DEI-related practices	How often do you observe your STEM instructors introducing themselves with their pronouns, or including pronouns in their email signature?	(31)
	How often do you observe your STEM instructors explicitly mentioning their intentions for inclusivity in the classroom?	(31)
	How often do you observe your STEM instructors asking for student feedback about the degree of inclusivity seen in the classroom?	(31)
	How often do you observe your STEM instructors mentioning their own identities and lived experiences, and how that informs their experiences in education?	(10, 31)
	How often do you observe your STEM instructors appropriately responding to microaggressions that occur in the classroom instead of ignoring them?	(31, 32)
	How often do you observe your STEM instructors addressing potential harm caused by microaggressions that occur in the classroom in an appropriate and timely manner?	(31, 32)
Science identity	*Assess to what extent each statement is true of you*	(5)
	I have a strong sense of belonging to the community of scientists	(Cronbach's alpha in
	I have come to think of myself as a "scientist"	our sample: 0.856)
	I feel like I belong in the field of science	
	The daily work of a scientist is appealing to me	
Science self-efficacy	*Rate your confidence in the following skills:*	(5)
	Use technical science skills (tools, instruments, and techniques)	(Cronbach's alpha in
	Generate a research question to answer	our sample: 0.790)
	Identify what data to collect and how to collect them	
	Create explanations for results of a study	
	Use scientific literature and/or reports to guide research	
	Develop theories (integrate and coordinate results from multiple studies)	
Self-esteem	*Assess to what extent each statement is true of you:*	(30)
	On the whole, I am satisfied with myself	(Cronbach's alpha in
	At times, I think I'm no good at all	our sample: 0.856)
	I feel that I have a good number of qualities	
	I am able to do things as well as most other people	
	I feel I do not have much to be proud of	
	I certainly feel useless at times	
	I feel that I'm a person of worth	
	I wish I could have more respect for myself	
	All in all, I'm inclined to think I'm a failure	
	I take a positive attitude for myself	
Demographics / Identities	Race and ethnicity	
	Gender identity	
	Sexual orientation	
	Age	
	Major(s)	
	First-generation status	

(*Continued on next page*)

TABLE 1 Survey items (*Continued*)

Construct	Items	References
	Socioeconomic status	
	Disability versus ability	
	Religious and spiritual affiliation(s)	

practices is greater when there is a department-wide effort towards this, emphasizing the importance of our bidirectional scale in measuring whether some or most instructors are implementing the practices.

Survey distribution

This study was approved by the Institutional Review Board of Colorado State University. Survey distribution was completed via snowball sampling. Caley J. Valdez performed the snowball sampling, capitalizing on her identities as a fellow undergraduate student in STEM who holds some marginalized identities (see Positionality statement). Snowball sampling by members of marginalized groups has been shown to increase the

A

Survey item response and Nominal value for statistical analysis (Chi Square)	Ordinal value for statistical analysis (t-tests and linear regressions)	Bidirectional coordinates for data visualization (see axes in Fig 1B)
Never	1	(0,0)
Some of the time with some instructors	2	(1,1)
Some of the time with all instructors	3	(2,1)
All of the time with some instructors	4	(1,2)
All of the time with all instructors	5	(2,2)

B

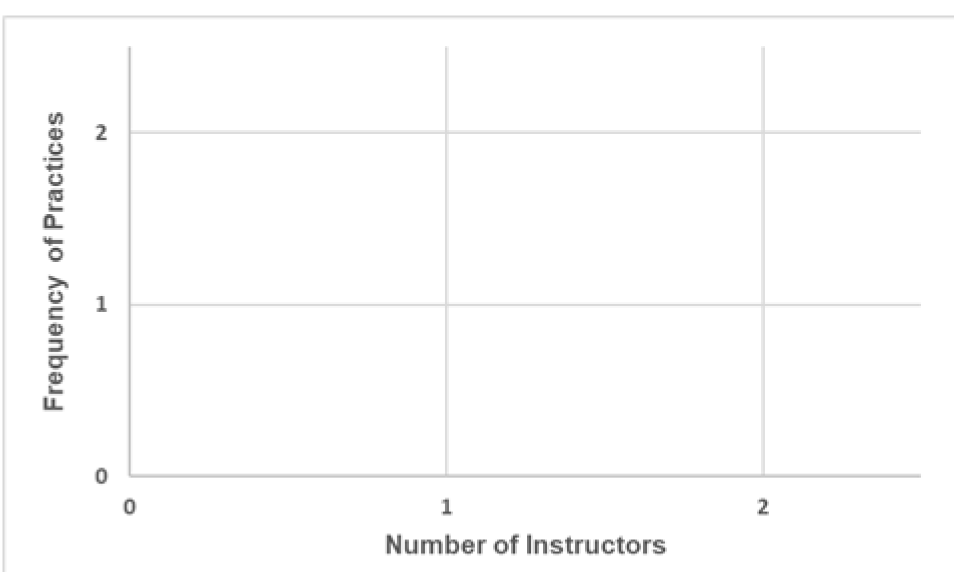

FIG 1 Novel survey responses for how students observed various types of inclusive pedagogy in the classroom. (A) Table indicating survey responses for each inclusive pedagogical practice as well as how we operationalized this data for further analysis. (B) Axes utilized for bidirectional visualization of data.

representation of such populations in survey studies (37–39), and we wanted to ensure we were studying the perspectives of marginalized students. In total, undergraduate students (n = 74) completed the survey; demographics are listed in Fig. 2 and majors of the students are listed in Table 2. The biomedical sciences program at the university is primarily for women, and this major was the most heavily represented. Much of our sample is various life science majors, and there is a strong overlap between the courses in these majors that students take, so many of the students in our sample will have observed similar STEM courses.

Statistics

We utilized chi-square to compare how students noted both the number of instructors and frequency of use by those instructors of inclusive pedagogy. We utilized unpaired *t*-tests to compare how students noticed one type of inclusive pedagogy versus another or how different groups of students noticed the same type of inclusive pedagogy. We utilized simple linear regressions to analyze how observations of inclusive pedagogy correlated with SAMs.

RESULTS

To answer RQ1 regarding what inclusive pedagogy students notice in the classroom, we first examined how students rated all of the 11 practices. We analyzed the data in three ways. First, we treated our scale as ordinal to demonstrate the relative observation of each practice by students (Fig. 3A). Next, we treated our bidirectional scale as a nominal/categorical scale for chi-square analysis. This enabled us to quantify and compare whether students are noting explicit DEI practices or inclusive instructional practices more. Students noted more inclusive instructional practices than explicitly DEI practices $\chi 2$ (4, N = 72) =26.25, P = 0.000028 (Fig. 3B). Next, we performed data visualization of our bidirectional scale of number of instructors versus frequency of use of practices further (Fig. 3C and D). This visualization further highlights that inclusive instructional practices like active learning are being used much more frequently than explicit DEI practices like sharing pronouns.

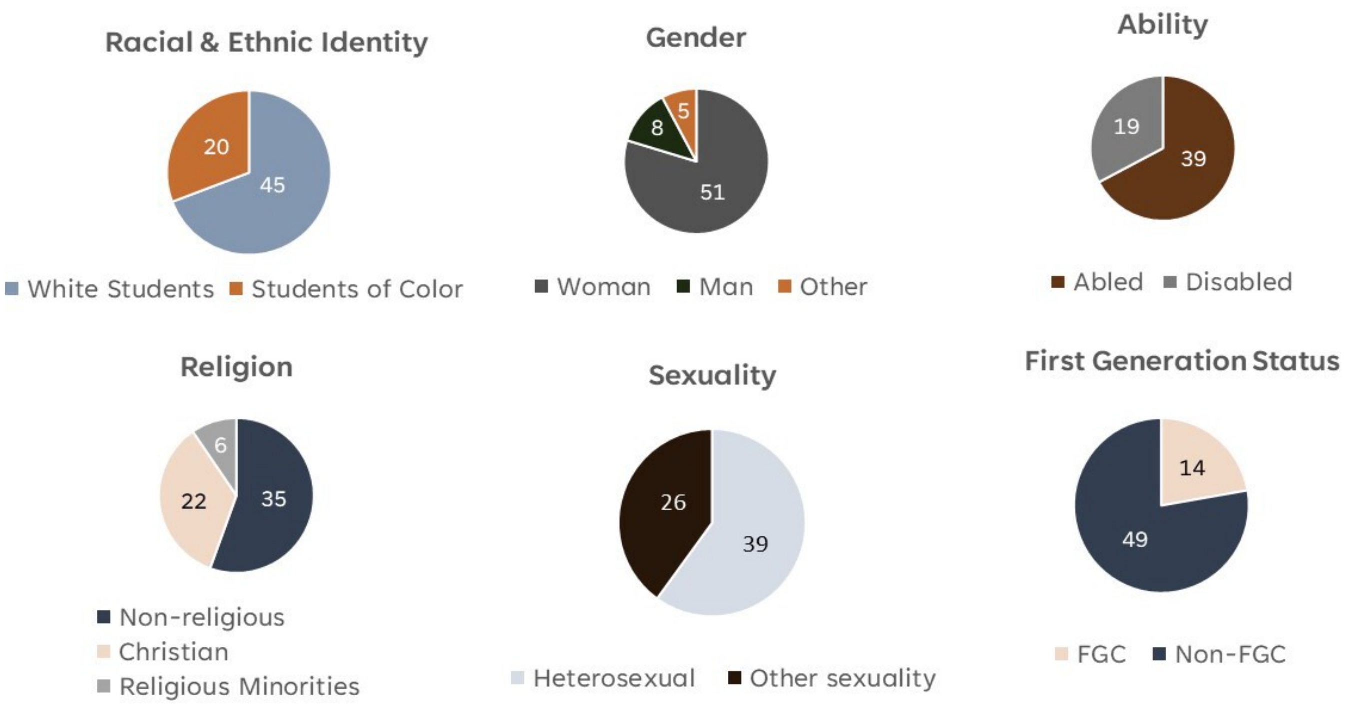

FIG 2 Demographics of survey respondents.

TABLE 2 Majors of survey respondents

Major	Students (n = 74)
Biomedical Sciences	26
Biology	6
Neuroscience	4
Psychology	7
Health and Exercise Science	2
Zoology	6
Natural Sciences	1
Civil Engineering	1
Biomedical Engineering	2
Chemical Engineering	1
Fish, Wildlife, and Conservation Biology	2
Equine Sciences	2
Ecosystem Science and Sustainability	2
Animal Science	1
Biochemistry	3
Chemistry	1
Nutrition and Food Science	1
Students with >1 Major	5
Students with 1 + Minor(s)	30

In order to analyze how student identity impacts their observation of instructional practices, we utilized unpaired t-tests of the ordinal values to assess whether white students or Students of Color noticed more of each type of practice. We elected to analyze these two groups of students since retention of Students of Color in STEM remains inequitable (40). We found that white students noticed more explicit DEI practices than did Students of Color (P = 0.019). There was no significant difference in how identity impacted students noticing the frequency of inclusive instructional practices (P = 0.119). For both groups of students, they noticed more inclusive instructional practices than explicit DEI practices (Fig. 4A and B).

In order to answer RQ2 about how student perceptions of inclusive pedagogy impacted their affective measures, we utilized simple linear regressions of the ordinal values. There was no significant impact of observing inclusive pedagogy (inclusive instructional practices and explicitly DEI-related practices) on the SAMs, we assessed for all students grouped together (Table 3). These findings were true for both white students and Students of Color (separated data not shown), suggesting that student racial identity did not impact the relationship between their observations of inclusive pedagogy and their affective measures.

DISCUSSION

Findings and implications for science education

Overall, we found that undergraduate STEM students have different perceptions of what forms of inclusive pedagogy they are seeing or not seeing in STEM classrooms. Primarily, they reported observing inclusive instructional practices such as active learning more than they noticed explicitly DEI-related practices such as sharing of pronouns. White students reported more explicitly DEI-related practices than Students of Color did. This may be because white students notice such practices more, or because Students of Color are particularly cognizant of lack of these practices. Noticing inclusive pedagogy in the classroom does not impact student science identity, science self-efficacy, or self-esteem, regardless of identity.

There are two potential reasons for our findings: instructors are utilizing less explicitly DEI-related practices in the classroom, and/or students are perceiving less use of these practices. Fortunately, lack of perception of these practices is not detrimentally affecting

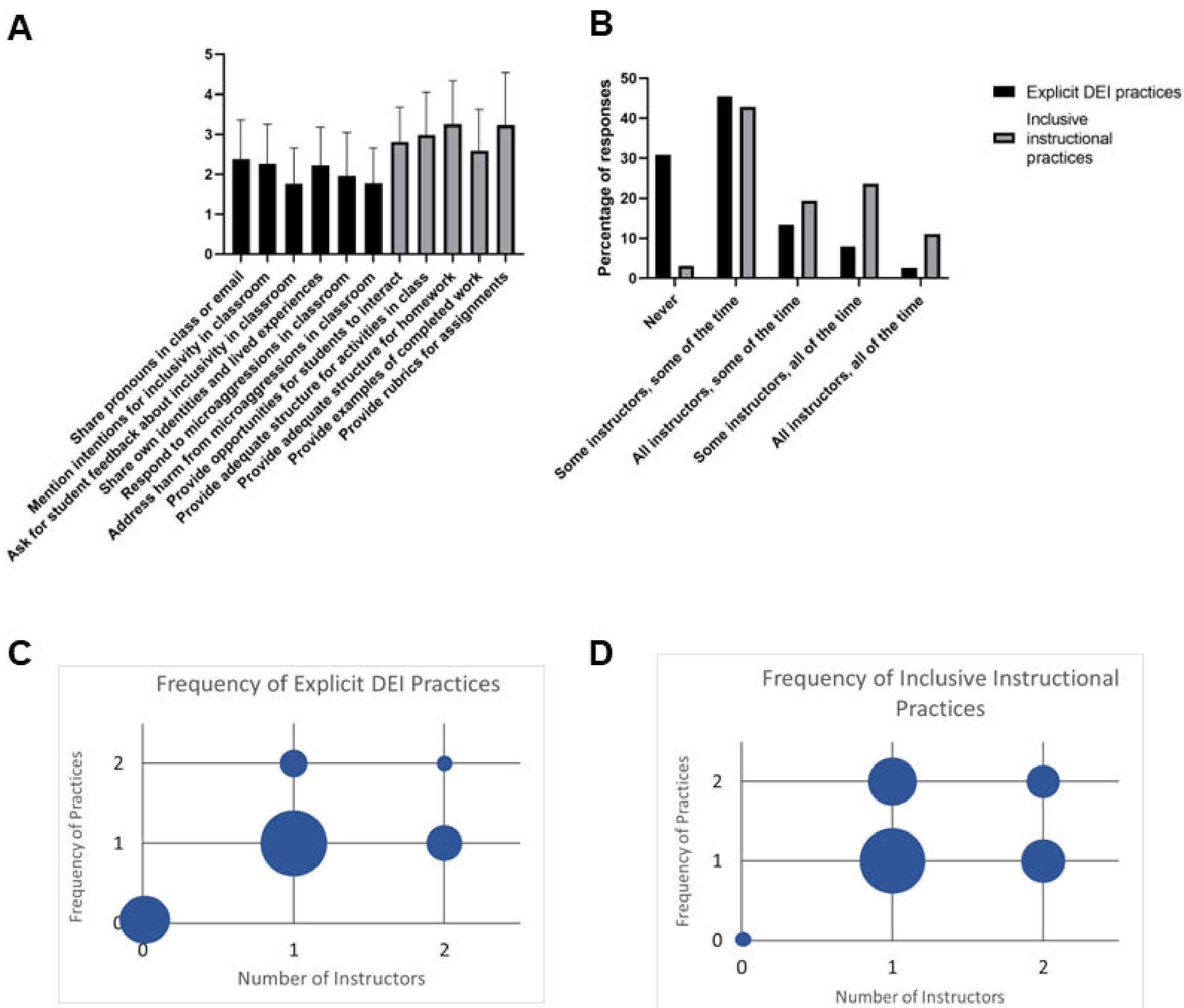

FIG 3 Data visualization of categorical data for how all students observed the different practices. (A) Data shown with an ordinal scale for every practice. (B) Data shown with a nominal scale as percentage of total responses for practices grouped by explicit DEI practices and inclusive instructional practices. (C) and (D) Data shown utilizing a bidirectional scale explained in Fig. 1.

student science identity and other affective measures. Likely, students are relying on other sources–such as cultural capital (6), student affairs (41, 42), and/or their existing capital and resilience from previous experiences (43, 44)–to develop these factors and succeed in STEM. These findings indicate that there is room for growth in science education practice in terms of increasing DEI-related practices in the classroom. There is also room for growth in science education research in terms of assessing how lack of inclusive pedagogy impacts students and what metrics can be used to measure these impacts.

Limitations

The main limitation of this research is sampling. The research sampled more life science majors, which at our institution are predominantly identifying as female. Research into other fields in STEM, such as math or physics, may demonstrate different findings. Additionally, analysis of how a student majoring in one STEM discipline perceived coursework in another STEM discipline was not assessed in this study (45–48).

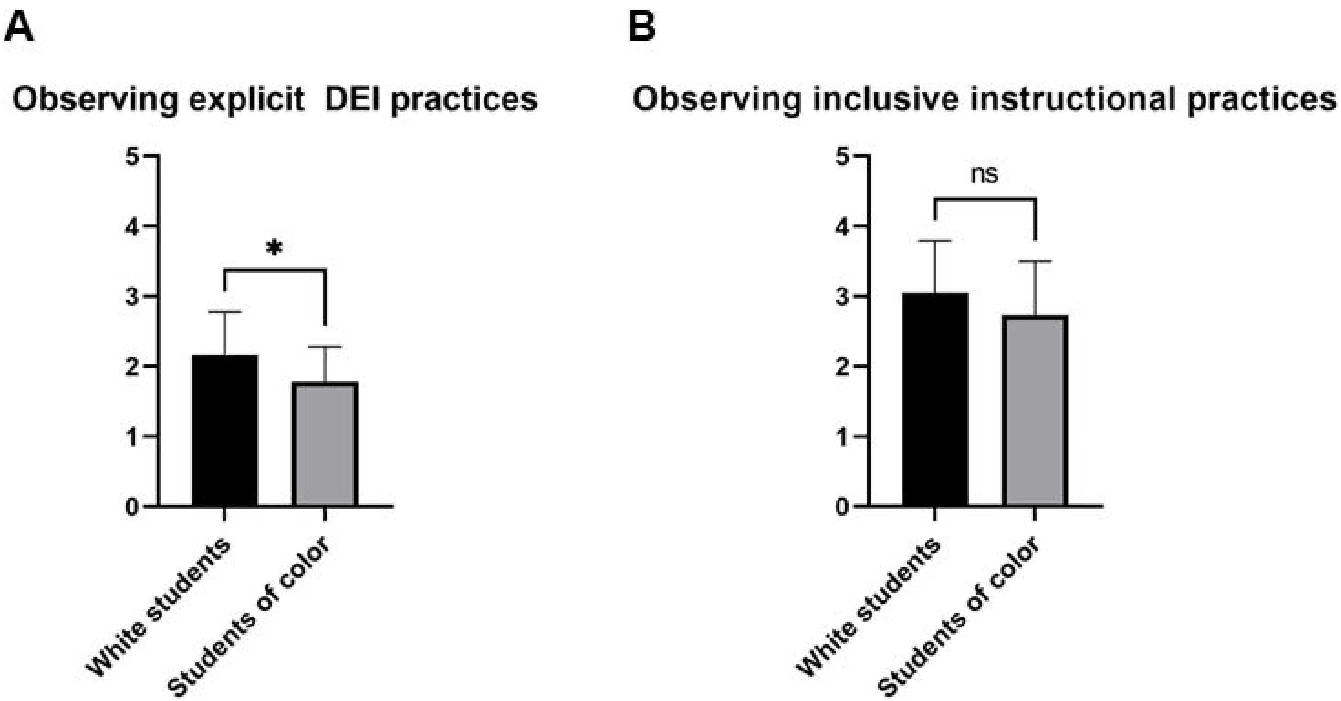

FIG 4 Comparison of how white students and Students of Color observed different types of inclusive pedagogy.

Future directions

To continue this research, interviews and focus groups with undergraduate STEM students should be performed in order to further analyze students' perceptions of inclusive pedagogy and how critical they think these practices are to their academic and psychosocial development. Such qualitative research may reveal other constructs that are affected by inclusive pedagogy (or lack thereof), which could be measured quantitatively with different affective measures than those we utilized in this study (16, 17, 21, 22, 25). For example, perhaps inclusive pedagogy could influence students' motivation rather than their science identity (21). Awareness of these constructs will enable evaluation of changes in response to increased inclusive pedagogy in classrooms over time. Finally, analyzing how STEM students are affected by non-STEM coursework, which was not assessed in this study, could shed light on effective incorporation of inclusive practices in non-STEM fields that could be adopted and adapted into STEM (49, 50).

Beyond these research directions, this work sheds light on potential lack of translation of research on inclusive pedagogy into the actual classroom practice of instructors. Further analysis of how instructors learn about, practice, and implement these practices is merited (46, 51–54), both for instructors of dominant and marginalized identities. Factors such as instructor mindset or institutional support may be important mediators of how instructors implement inclusive instructional practices and explicitly DEI-related practices.

TABLE 3 Analysis of influence of observation of inclusive pedagogy on student affective measures[a]

Predictor		Science identity	Science self-efficacy	Self-esteem
Observing inclusive pedagogy	Slope	0.3951	0.1432	0.04100
	F	3.668	0.9092	0.1099
	DFn, DFd	1, 63	1, 63	1, 63
	P value	0.0600	0.3440	0.7413
	R squared	0.05502	0.01423	0.001742

[a]Linear regression results for all students.

Applications of this work

Based on our findings in this study, there are several key applications. Notably, students are aware that many instructors are implementing instructional practices that increase inclusivity, such as active learning in the classroom. However, students often note a lack of explicitly DEI-related practices such as sharing pronouns or addressing micro-aggressions. Instructors should continue to adopt explicitly DEI-related practices into their teaching, to support all students but specifically Students of Color, who may be disproportionately impacted by lack of these practices in the classroom.

There is a strong body of work highlighting what faculty can do to incorporate DEI-related practices in the classroom and how administrators can support this work (55). First, it is important that faculty and administrators truly acknowledge the burden that racialized systems and lack of inclusive pedagogy places on marginalized STEM students (56). Additionally, trainings about anti-racism and other equity concepts should be coupled with explicit, tangible examples of how to incorporate these concepts into teaching (57). These trainings can include mentoring and collaborative learning with other faculty, which can increase faculty confidence in implementing inclusive pedagogical approaches (58). Finally, departments and institutions can assess whether or not DEI trainings are actually affecting teaching practice using validated rubrics [e.g., (29)]. Our work in this study to examine student perceptions of inclusive pedagogy adds another direction for assessing the efficacy and impact of efforts for faculty to increase the inclusivity of their STEM classrooms.

Positionality statement

Caley J. Valdez was an undergraduate STEM student at the Colorado State University while research was conducted. Additionally, Caley J. Valdez wishes to disclose that she is a first-generation student and a woman in STEM, along with other marginalized identities, which have resulted in barriers in STEM classrooms. Caley J. Valdez is also a white and US citizen, and she recognizes the privileges afforded because of those identities that the students and communities the authors wish to advocate for may not have.

ACKNOWLEDGMENTS

This work was funded by start-up funds to Nicole Kelp from the Colorado State University. Caley J. Valdez received programmatic support from the Colorado State University Honors Program as well as Faculty Traci Kinkel and Leann Kaiser for this research.

AUTHOR AFFILIATION

[1]Department of Microbiology, Immunology, and Pathology, Colorado State University, Fort Collins, Colorado, USA

AUTHOR ORCIDs

Nicole C. Kelp http://orcid.org/0000-0001-8462-5689

FUNDING

AUTHOR CONTRIBUTIONS

Caley J. Valdez, Conceptualization, Data curation, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review and editing | Nicole C. Kelp, Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Supervision, Writing – original draft, Writing – review and editing

ETHICS APPROVAL

This work was approved by the Institutional Review Board of Colorado State University.

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