Fostering inclusion and teaching equity in a Modern Physics for Engineers course

Dr. Jessica R Hoehn, University of Colorado Boulder

Dr. Jessica R. Hoehn is a postdoctoral researcher at University of Colorado Boulder. She received her PhD in Physics Education Research from CU, studying ontological, epistemological, and social aspects of student reasoning in quantum mechanics. Dr. Hoehn's current research interests include connections between epistemology and group work in learning physics, the role of writing in lab classes, and students' epistemological views about experimental physics. Generally, Dr. Hoehn is interested in valuing the messiness of learning and fostering equitable and inclusive educational environments.

Prof. Noah D Finkelstein, University Colorado Boulder

Noah Finkelstein is a Professor of Physics at the University of Colorado Boulder and conducts research is in physics education, specifically studying the conditions that support students' interests and abilities in physics - developing models of context. In parallel, he conducts research on how educational transformations get taken up, spread, and sustained. He is a PI in the Physics Education Research (PER) group and a co-director of CU's Center for STEM Learning. He co-directs the national Network of STEM Education Centers, is building the STEM DBER-Alliance, and coalitions advancing undergraduate education transformation. He is involved in education policy serving on many national boards, sits on a National Academies' roundtable, is a Trustee of the Higher Learning Commission, is a Fellow of the American Physical Society, and a Presidential Teaching Scholar and the inaugural Timmerhaus Teaching Ambassador for the University of Colorado system.

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Introduction

Physics and engineering educators are increasingly attending to diversity, equity, and inclusion in our educational environments (e.g., [1], [2]). One of the student outcomes in the ABET criteria includes "an ability to function effectively on a team" and to "create a collaborative and inclusive environment" [3, p. 6]. Creating classroom cultures where students feel included and supported is crucial for students' sense of belonging, identities as scientists and engineers, learning, and persistence in STEM [4]–[9]. Through creating inclusive environments in our classes, we can help our students learn to engage in effective, respectful, and equitable collaboration. Even further, we can empower students to examine who has access to, and is included in, the scientific community. To that end, we consider investigations of who does physics to be a part of physics itself, and build on a growing effort at the K-12 [10]–[12], introductory [1], [2], and teacher education [13] levels to include these discussions in our upper level classrooms.

We present on a two-pronged instructional approach in a Modern Physics for Engineers course at the University of Colorado Boulder (CU Boulder) in which we: a) construct an inclusive environment through course structure, policies, and practices and b) implement a course unit engaging students in explicit discussions around representation and diversity in STEM. In this paper, we describe the goals and implementation of this integrated approach to fostering inclusion and teaching equity in a Modern Physics class (N=120). We report results of some preliminary analyses to assess the impact our approach has on both individual students and the class as a whole. We see a high rate of reported sense of belonging at the end of the semester, and provide examples of unprompted student feedback identifying specific elements that made the class feel like an inclusive and supportive environment to them. We also report on students' general reactions to our in-class discussions around diversity and representation in STEM; overall, students respond positively and see these conversations as an important part of learning physics. To complement quantitative measures of impact, we also provide an example of positive impact on an individual student. In assessing the impact of our approach, we bring the perspective that evidence of impact on individuals (in the form of individual written work, feedback, or quotes from class) can complement and be just as meaningful as, if not more than, quantitative measures of class-wide impact. We consider that the impacts on individuals can be profound, positive, and far exceed the efforts required to implement such a curriculum.

Background

Engineering, physics, and computer science continue to award fewer degrees to women than other STEM disciplines, and the numbers remain disproportionately low for African-American, Hispanic, and Native American men as compared to the college-aged population [4], [14]–[16]. Persistence of disparities in representation points to the role of culture in determining who and what constitutes STEM fields [4], [17]. The implicit cultural values of science (e.g., the belief that science is race, ethnicity, and gender neutral) impact students' experiences in STEM classrooms, and can often been discouraging for, or hostile towards, students with marginalized identities [18]. Thus, in addition to recruiting more women and people of racial and ethnic minorities into fields such as engineering and physics, we must simultaneously focus on creating *environments* that are inclusive and supportive of all students, especially those from underrepresented groups.

Inclusive pedagogy refers to creating space for, and teaching, a diverse array of learners [19],[20]. Inclusive pedagogical practices can involve knowing students names, using culturally diverse and relevant examples, allowing students to demonstrate their knowledge in multiple formats, or employing active learning strategies that focus on inclusion [21]. Recent research in STEM education demonstrates that active learning benefits all students, and can have disproportionately positive benefits for students of underrepresented groups [22]–[24]. However, the existence of active learning does not necessarily ensure equitable and inclusive classroom interactions [25], [26]. One important factor that contributes to making a space inclusive is a sense of belonging [4], [5]. Increased sense of belonging in an academic context has been linked to students' persistence in STEM [6]–[8], and increased sense of social belonging may also have impacts beyond the academic sphere, benefiting students' health and well-being [27]. To build a sense of social belonging, academic belonging, and well-being for students in our classroom, we attend to four factors that can contribute to fostering belonging and identity—*community*, *agency*, *voice*, and *representation*.

Rambo-Hernandez *et al.* [1] implemented a series of research-based activities in a first year engineering course with the goal of helping students see the importance of diversity and engaging in equitable team work. They assessed the impact of the diversity-oriented curriculum on students' appreciation for diversity in engineering and their tendency to engage in inclusive behavior during team work using the Valuing Diversity and Enacting Inclusion in Engineering Scale [28]. The authors report a small effect of the intervention but note that the quantitative measures were high to begin with and thus they need to find alternative approaches to evaluating the impact of these activities. In this paper, we present examples of how we have attended to these topics in our Modern Physics for Engineers class, and provide both qualitative and quantitative data as evidence of impact on individuals and the class as a whole.

Daane, Decker, and Sawtelle [2] implemented a four-day equity unit in an introductory physics class to help students reflect on racial (in)equity in physics. Their course materials were designed specifically for use in predominantly white settings. We draw on these materials in order to incorporate discussions about representation in STEM in our Modern Physics class, focusing on a smaller subset of topics ("What is science?" and "Who does science?") and tailoring them to the upper-level class environment and content of modern physics.

University and course context

CU Boulder is a large, public, research institution. The course that we report on in this paper is a Modern Physics for Engineers course, housed in the physics department. This class satisfies a requirement for many engineering majors; the majority of students typically enrolled in the course are mechanical engineering, followed by electrical engineering, and other engineering or physical science majors. The College of Engineering at CU Boulder is 25% female and 75%

male, and 16% of students are first-generation college students. The racial demographics are: 67% white, 10% Asian, 10% Hispanic/Latino, 8% International, 2% African-American, 1% American-Indian/Alaska Native, <1% Native Hawaiian/Pacific Islander, and 2% Unknown [29]. Our Modern Physics course typically enrolls between 75-120 students each semester, and the student population reflects the demographics of the College of Engineering.

Modern Physics for Engineers is the third semester of the introductory physics sequence, which serves as an introduction to quantum mechanics (QM). It is considered to be a “sophomore-level” course, though many students do not take it until their junior or senior years. The version of the class that we teach is the result of several years of course transformation [30], [31]; the approach that we present here is an example of the continual effort to transform and improve students’ experiences and learning in the course. The course is a lecture course that meets for 75 minutes twice per week, with several hours of additional help sessions each week that students are encouraged, but not required, to attend. There is heavy use of interactive engagement (primarily in the form of clicker questions and in class tutorials), the grading policies emphasize reasoning over correct answers, and homework and participation in and out of class are weighted heavily in the overall grade. Topics of the course include: wave and photon models of light, photoelectric effect, models of the atom, spin and Stern-Gerlach experiments, quantum entanglement, EPR paradox, single photon experiments, Schrödinger equation, infinite and finite square wells, quantum tunneling, and various applications of QM (e.g., scanning tunneling microscope, semiconductors, LEDs).

In the following sections, we present our approach and outcomes for: a) fostering an inclusive environment through a collection of teaching practices and course structures, and b) implementing a specific unit which engages students in conversations around diversity in STEM.

Fostering a culture of inclusion

Approach

In order to create an inclusive environment, we focus on four elements—community, voice, agency, and representation—that are considered to be important for cultivating a sense of belonging [4]–[9]. We embed each of these components of pedagogical practice throughout every aspect of the course, and provide examples of these below.

Forming community: We begin the semester by taking time in class to have the students introduce themselves to one another—a simple (and perhaps seemingly unnecessary) activity that sets the tone for the rest of the semester and signals that we are committed to forming a community. We then engage the students in a fifteen minute activity to collectively construct a list of group and course norms, which applies to their interactions and various forms of collaboration throughout the rest of the semester. Starting with a list of suggested norms that we provide, students discuss in small groups anything they want to add, remove, or emphasize, then they report out to the whole class, and we post the final list of group norms on the website and remind students periodically in class lectures. Throughout the course, students provide feedback on pace, content, and processes of the course, both individually and through collective discussion.

Group work: As an important and realistic engineering or scientific practice, group work is embedded thoroughly throughout the class. During lecture, students work in groups on clicker questions (every class) or on longer tutorial activities (3-5 whole class sessions throughout the semester). Outside of class, students are encouraged to attend optional homework sessions in the department's Help Room. There they can receive guidance on their weekly homework from the undergraduate and graduate teaching assistants, but students who attend usually spend most of their time working in groups together. Outside of class, students also interact with one another online. Many weeks the students must complete a reading assignment which consists of reading an article about QM or the nature of science (see the "Teaching Equity" section below) and then posting comments and responding to others' comments. We have used both NB [32] and Perusall [33] for these reading assignments, which allow students to comment and engage in discussion directly on the PDF. These discussions build community and allow students to interact with peers that they do not normally encounter in class or in the Help Room. It also provides a platform for students to share their ideas in a format other than in-person dialogue or a graded homework assignment. Because there are no "right" answers or specific discussion questions, students get to use their voice to shape the discussions that happen online. Members of the instructional team monitor the online discussions and join in every once in a while, but the students primarily control these collective discussions. Lastly, students also collaborate on exams. For the first three quarters (~60 minutes), students complete an individual exam that includes multiple-choice and short answer questions. Upon completion of the individual exam, students assemble in their groups of 3-4 and repeat the multiple-choice portion of the exam together as a group. The group exam score can only raise students' grades, and tends to do so for at least 75% of the class. Two-stage exams are becoming more common in physics (e.g., [34], [35]), and can be beneficial for students' learning, their grades, and mitigating exam stress and anxiety. It also gives students practice in advocating for their ideas in a supportive environment, as well as a chance to engage in community, and maybe even enjoy themselves[1].

Student-driven learning: Each week, students have the opportunity to complete an optional online feedback survey, providing comments about the pace of the course, how well they feel they are learning the material, or their experience of a particular activity or assignment. We respond to the feedback publicly by posting anonymized comments and responses on the website, and often adapt substantial aspects of the course based on student feedback. In this way, students have a voice in shaping the class. Additionally, students vote on topics to cover for the last few weeks of the semester; this community process allows them to further exercise control over their own learning. Students also have agency over their learning at the end of the course when they can complete an optional final project. The projects typically consist of writing a paper about a topic we did not cover in depth in the course, and can replace part of an exam grade. In addition to having agency over their learning, the final project option also provides opportunity for students to define what is interesting and important to them in modern physics. They also have the option to reflect on their learning in the course and are provided with a variety of suggested questions to guide their reflection. Each semester, a couple students choose to do the reflection essay for their project.

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[1] On a several occasions, upon exiting the exams or in end-of-term comments, students have reported that the group exams are *fun*!

Highlighting diverse science and scientists: Over the course of several semesters, we have intentionally increased the diversity of scientists we highlight in lecture materials. Focusing primarily on the advent of QM in the early 20th century, Modern Physics classes historically focus on scientists like Einstein, Bohr, and Schrödinger. We complement the celebration of famous white male physicists with additional and intentional discussions about the often overlooked contributions of women. For example, we highlight the work of Marie Curie and Lise Meitner in the unit on radioactivity (including photos, quotes, and discussion of their lives as scientists) and elsewhere mention female scientists' contributions to modern physics (including highlighting the contemporary research at our university whenever possible). This serves to address the representation aspect, messaging to students that women and people of color make great contributions to science and should be celebrated.

Through the collection of these course practices and the way they interact with one another, we strive to create an inclusive class community where students feel valued, welcomed, and supported (by us and by their peers).

Outcomes

One way to evaluate the impact of our inclusive pedagogical practices is to measure students' sense of belonging through Likert scale survey items [7]. On a survey at the end of the course that included questions on QM content as well as students' beliefs about learning QM, we asked them to respond to the statement, "I feel like I belong in this Modern Physics class" by choosing "strongly disagree", "disagree", "neutral", "agree", or "strongly agree." For the purposes of analysis we collapse the responses to a three-point scale. Figure 1 shows that 70-78% of students reported having a sense of belonging in the class at the end of the semester, for each of the three iterations of our class, which far outweighs the negative (8-11%) and neutral responses (14-18%). This is equivalent to physics students' sense of belonging in similar Modern Physics classes for physics majors at our university. We might expect the physics majors to have a higher sense of belonging in a physics class than engineering students would. The fact that we see comparable rates of belonging among the engineering students in our class is encouraging. Further, we note that the percentage of students reporting feeling a sense of belonging has increased each semester with our continual refinement of the curricula and pedagogical practices (though the differences are not statistically significant).

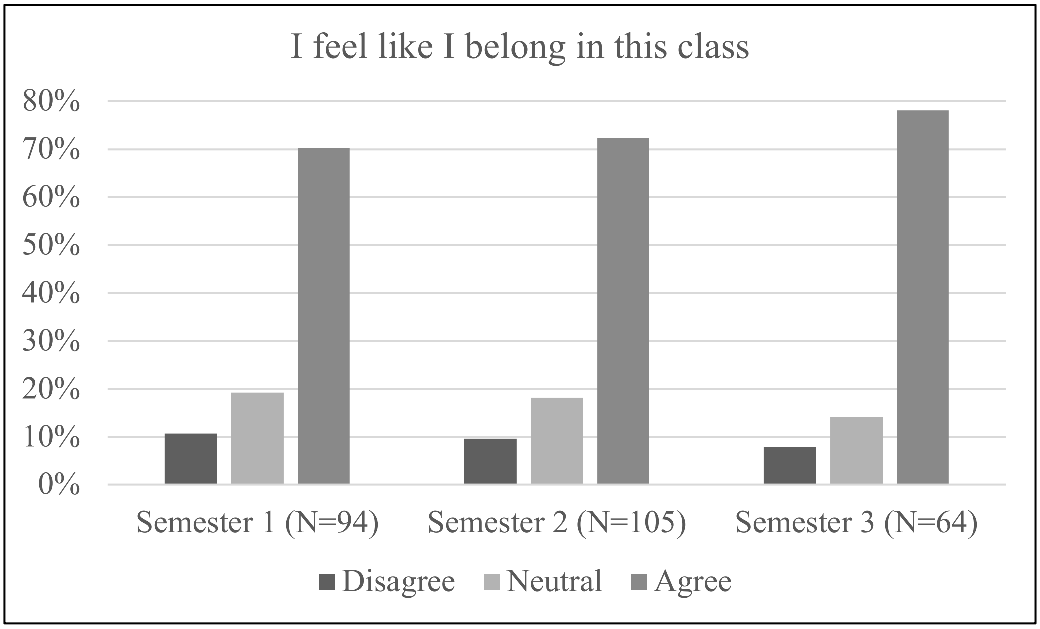

Figure 1. Students' reported sense of belonging in the class at the end of the semester.

In addition to quantitative data from survey items, we have evidence of students' perception and experience of a culture of inclusion in our classroom in the form of unprompted responses to feedback surveys or other course artifacts. For example, one student who submitted a reflective essay for their final project identified group work as the most beneficial aspect of the course:

> *"Time and time again, higher education seems to feel like a competition and while I do understand that competition incites progress, I also know that collaboration leads to more ideas being presented and a deeper understanding of the material…[Group work in this class] has also taught me to be responsible for my own learning because it is a group effort in the end. I know it could be easy to rely on group members heavily in this class, but instead this structure lead me to think that it is necessary to contribute in some way to better myself and those around me. When it comes down to it, we are responsible for the material and that was proven in the individual part of the exam. The group aspect has also gotten me to reach out to others more in my field, whereas I don't think I've ever done that before. This is partially because I felt that I didn't feel like I could relate or connect to my peers, and I eventually realized that that's not true at all."*

Not only did this student see group work as useful for their learning of the course content, but they comment that it helped them exercise agency over their own learning, something that had both personal and collective benefit. The implementation of group work in the class forced this student to make connections with their peers, helping to build a sense of community. In this way, the elements of *agency* and *community* that we emphasize in the design and structure of the course work together to create a positive learning experience for this particular student. Other students also commented on the positive impact of group work on their learning and their sense of belonging. For example, one student appreciated the regular groupwork in class around clicker questions:

"I think in bigger classes it's hard to feel comfortable talking to the people around you if they are strangers. I feel more comfortable knowing there are always 3 people I can bounce my ideas off of."

The fact that we even have these unprompted quotes from students suggest that they have a *voice* in the classroom community, and that they recognize and utilize that voice. On an optional weekly feedback survey, one student expressed appreciation for the opportunity to provide feedback and shape the direction of the course:

"I just want to say thank you for listening to our suggestions and modifying the course as we moved toward the end of the semester, it really made my experience better and this is definitely encouraging to spend a real effort on giving these feedbacks!"

By soliciting students' feedback and then acting on it (when possible), we signal to them that they their voice in the classroom matters.

Teaching equity by addressing diversity in STEM

Approach

Fostering a culture of inclusion in the classroom makes it possible to engage in discussions around topics (like diversity, equity, race, and gender) that often feel taboo, threatening, or scary to teachers and students alike, *especially* within a physics course. Drawing on the materials of Daane, Decker, and Sawtelle [2], we integrate such discussions into our class by splitting them into two parts, each of which is roughly one full class meeting. Part one—"What is science?"—focuses on the role of models, theories, and interpretation in the process of science, and concludes with students investigating science as something conducted by a community of people. In part two—"Who does science?"—students explore data on representation in STEM fields (e.g., [14]) and engage in an activity to make sense of the data, followed by a class-wide discussion around why representation matters. For each of the two parts, students engage with the material in and out of class through lectures, class discussions, in-class activities, preparatory and follow-up readings, homework, and exam questions. In this way, we strive to call out issues of equity and inclusion as their own important topics yet also embed them throughout the course to signal that they are central to the learning of physics.

The approach we describe here is the result of three semesters of implementing the unit and modifying each time based on student feedback, student engagement, and our continually developing understanding around these issues.

Part one: What is science?

The learning goals for the first part of the unit are for students to be able to recognize and articulate the differences between models, theories, and interpretations in the process of science, and to recognize the role of people in science. Here, we focus mostly on the latter but note that the former is an important aspect of the course. This unit connects seamlessly with other topics in the course as we begin by introducing the photon model of light (and contrasting it with a wave model), and then move into talking about models of the atom. We engage in an in-class nature of science activity called *The Farmer and the Seeds* [36], where students practice modeling a system, creating theories, testing theories with experiments and evidence, and interpreting the results. They also have an assigned reading on the nature of science [37] which describes science as a way of thinking, discusses the role of scientific theories, characterizes the scientific process as messy and non-linear, and emphasizes the role of collaboration while also highlighting the role of individuals in science. Students discuss the reading online, and then compare the reading to *The Farmer and the Seeds* activity. They also respond to questions on their homework about the reading and their understanding of the role of models, theories, and interpretations. We also post a few optional readings that provide additional perspectives on the nature and culture of science. In total, this part one of the unit opens up questions like "*Who gets to participate in the scientific community?"* and "*How do scientists bring the personal into their work?*", which are used to lead into part two.

Part two: Who does physics?

The goals of part two are that students are able to define the term "equity", investigate and interpret data about who participates in STEM, identify the lack of diversity in STEM, and reflect on why representation matters (if at all). Additionally, we want students to consider whether thinking about who does science is something that should be included in a physics class[2]. We begin class by reminding the students of our collectively agreed upon group norms, and then engage in an activity where we have the students google "famous physicists" and note any patterns they see. This initiates our conversations about representation, as students will notice that most of the google images of physicists are white men. Following this initial activity, we have a brief discussion about the terms equity and equality. The students then engage in a data interpretation activity—we give them a packet of graphs that show representation in STEM along various dimensions (race, gender, LGBTQ+ identification), and ask them to first consider what information they can gather from the graph and then what it means. They work together in small groups on this activity, and then report out to the whole class about interesting things they discovered. Next, we conduct a notecard activity where every student writes an answer to the question, "(Why) does representation in STEM matter?" on a 3x5 index card. They trade cards twice with random peers such that they end up with an anonymous student's notecard. We then use this to facilitate a class-wide conversation around why representation matters, with students sharing their own response or (dis)agreeing with the response they read on the notecard they received. This conversation continues on the homework, as students are asked to further reflect on what the data mean and how they connect to equity (i.e., in what ways do the graphs provide evidence of inequities in our systems) and the nature, culture, or process of science. Additionally, students are required to read "An open letter to SCOTUS from professional physicists" [38], which is the response from more than 2000 physicists to the question posed by Chief Justice John Roberts, "What unique perspective does a minority student bring to a physics class?" Students read this letter and engage in discussion online with their peers, as well as reflect on the response on their homework. We also post a few optional readings for students who want to engage with this topic in more depth (e.g., on experiences of women of color in STEM [39]).

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[2] We believe that whether considering who does physics *is* physics is a political rather than a pedagogical question, but we want students to consider why these questions might be important or relevant to include in a physics class.

Outcomes

It is difficult to compare outcomes from our class to other classes because the inclusion of a specific unit on equity in a physics class is so unique. We have evidence of student thinking around issues of equity and inclusion in the form of feedback, homework short answer responses, comments on the readings, optional final project reflection essays, and students' verbal contributions to the in-class discussions. The existence of these data is a demonstration that it is possible to directly address equity and inclusion in an upper level physics classroom. Here, we provide some exploratory analyses of a subset of the data that we have collected, to illustrate the kinds of impacts this approach can have.

One measure of the impact of our specific unit on equity is the students' general reactions to having discussions about equity and representation in a Modern Physics class. After the Part Two in-class data interpretation activity and discussion, we asked students to provide their general reactions on the online optional feedback survey for that week. Typically, 25-50% of the class completes the optional feedback each week, and they do not shy away from providing frank and negative feedback when they have it. We downloaded all of the responses to the question specifically asking about the in-class discussions, anonymized them, and coded each response as being generally positive, negative, or neutral. A response is coded as positive when a student says that they liked the activity, that they think these discussions are important, or that the unit positively impacted them in some way. A response is coded as neutral if a student expresses ambivalence or a mix of positive and negative reactions toward the activity, says that they were not impacted in any way by the discussions, or says that these discussions are important but do not belong in a physics class. A response is coded as negative if a student says they did not like the activity, or they do not see it as meaningful or important. Examples of positive, negative, and neutral responses are shown in Table 1.

	Example response
Positive	*It was not some news flash to me. I am a minority student at a very white school, I deal with many of the obstacles discussed on a daily basis. I did find it useful to speak about.*
	I actually thought that this discussion was very eye-opening. Not only did I learn some interesting facts, but it helped me realize the lack of representation that is still highly relevant today.
	It seems so obvious to me that diversity in STEM is important in order to keep discussions in science moving forward, yet our world today still lacks this kind of thinking. This is why it is important to talk about it in classes because understanding the problem is the first step towards fixing it.
Neutral	*I know that these discussions on representation are important in STEM fields, but I feel that we should have done this as homework or something rather than using class time. This is because there are still a lot of [traditional physics] concepts that I feel we could still be learning further.*

	It made me uncomfortable kind of, not in a bad way but just something that I feel is weird.
Negative	*To be completely honest, these classes on the nature of science are not very interesting to me. I would prefer to get to learn about cool physics topics that could be useful, rather than this.*

Table 1. Examples of positive, neutral, and negative student responses to the in-class activity and discussion around representation in STEM. Responses were submitted via the online optional weekly feedback survey.

Figure 2 displays the results of our coding analysis for the three semesters we have implemented this unit (noting that the content and structures of the activities and framing of the activities has changed slightly each time). Overall, we note that the student reactions are largely positive, which we take as an indication of the success of the unit and the potential for positive impact on students. Further, the quotes in Table 1 suggest that these in-class discussions can be valuable for both students of majority and minority identities. Future work will investigate correlations between students' responses and demographic characteristics (e.g., race, gender, first generation status). We are encouraged by the overall positive response from students, but also find the negative responses to be expected and potentially productive. One of our goals for part two of the unit was to have students consider whether they think investigating who participates in STEM should be included in a physics class. The quotes in Table 1 illustrate that they are considering that question, even when not prompted explicitly.

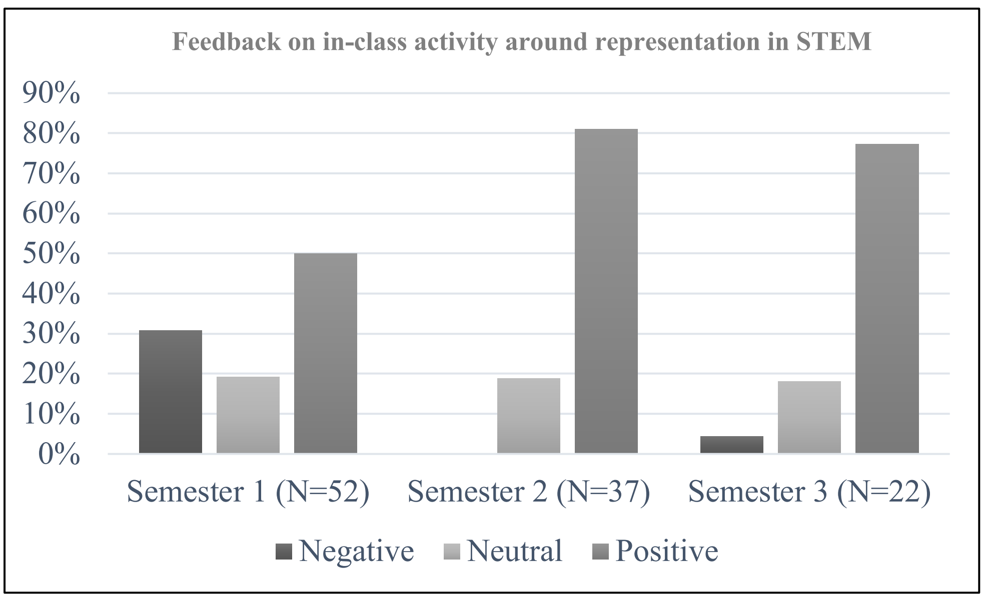

Figure 2. Students' general reactions to the in-class activity on representation in STEM, provided via the online optional weekly feedback survey. *N* indicates the number of students each semester who provided a response. Total enrollments in the course were 94, 104, and 64 respectively.

We can assess the overall impact of the unit by looking at students' feedback, responses, or reported sense of belonging and attending to the class as a whole. However, impact on individual students can be just as important, if not more. Here, we provide one example of the positive impact our unit addressing representation in STEM had on one student who identified herself as a woman and member of a racial/ethnic minority. Alyssa (pseudonym) was a physics major[3] enrolled in our class, and chose to write a reflection on diversity in physics for her optional final project, titled, "Defying the Odds." She begins by identifying the impact of our in-class data interpretation activity:

> *"We devoted an entire class to addressing the uneven distribution of the "types" of people within the physics field. This class opened my eyes. It may have been one of the most influential classes I have attended to this day. The class brought to light facts I had never even considered in why females and minority groups are turned off from pursuing physics-related fields."*

Alyssa describes the unit as being beneficial because it allowed her to question, and recognize, for the first time *why* women and people of color are absent from the discipline of physics. She then describes how her own experiences in STEM have been made more difficult because of her identity:

> *"I feel as though as a woman (as I'm sure many others do), I need to work harder, or excel beyond other men, in order for my input to even be considered as valuable."*

One of our goals for the unit was for students to consider whether investigating who participates in STEM is (or should be) an important part of learning physics. Alyssa answers this question as she describes the importance of this class to her personally:

> *"This classes addresses tough topics, beyond physical material. While learning quantum mechanics is the primary focus, this is the perfect class to tie in challenging societal norms and stigmas. I say the word "engineer" and an image of a white male almost instantaneously appears in my mind."*

For Alyssa, her own awareness of the lack of representation in STEM (i.e., the salient stereotype of a white male engineer) is an indication that conversations about representation are sorely needed in our physics classrooms. She concludes the paper with an affirmation of her own identity and belonging:

> *"I took this course to defy odds. I took it to be among the small group of minorities pursuing a degree in physics. I took it to be one of the few women who can proudly call themselves a physicist."*

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[3] Though the class is intended primarily for engineering students, physics majors can also choose to take it instead of the Modern Physics for Physics Majors course. Students typically do so based on the instructors of each course, or because of scheduling constraints.

Alyssa's final project reflection is an example of how our inclusive practices and curricula incorporating conversations about equity may have disproportionately positive impacts on underrepresented students. Given the role that belonging and identity can play in students' persistence and well-being [8], [27], the positive impact of this class on Alyssa may have far-reaching benefits.

Discussion and conclusions

We have described our integrated approach to a) fostering a culture of inclusion and b) incorporating discussions of representation in STEM in our Modern Physics for Engineers class. While these two pieces mutually inform one another, we believe that you cannot successfully implement the latter without first attending to the former. That is, we strive to *first* create a classroom culture of inclusion, where students' interactions with instructors and peers are respectful and supportive of their learning. When there is a sense of community in the class, and students feel comfortable engaging in the messy process of learning with one another, discussions around equity are more likely to be respectful, productive, and meaningful for the students. In designing our curricular approach and pedagogical practices, we lead with the intention of being inclusive, rather than starting with active learning techniques, which are generally beneficial for student learning but not necessarily guaranteed to create an equitable environment for students [25], [26]. Underpinning each of the pedagogical practices and techniques used in our course is a sense of being human, empathetic, and caring toward one another. Students respond positively and thrive in this environment, as evidenced by the high rates of sense of belonging and the unprompted feedback from students describing their perception of an inclusive environment.

Beyond creating an inclusive classroom environment, we implemented a specific unit in our course on "What is science?" and "Who does science?", directly addressing contemporary issues of equity and inclusion relevant to STEM disciplines. We see that these discussions positively impact students overall—the majority of students in our class see the issue of representation as salient to their experiences in STEM and are appreciative of the opportunity to address it in a physics class. We provide the example of Alyssa's final project reflection on diversity in STEM to illustrate how these activities can be empowering for students, impacting their sense of belonging and identity. These impacts may have far-reaching benefits for this student's persistence and well-being [6]–[8], [27], and we note that incorporating discussions about representation in STEM in our classes may be disproportionately beneficial to students of underrepresented groups.

As expected, not all students reacted positively to spending class time discussing the nature of science and investigating the people that participate in the scientific community, at the expense of covering more traditional physics content. We argue that even this pushback from students can be productive because it provides awareness in a safe and respectful way. For students who have only ever experienced a "decontextualized construction of science" [18] and thus never considered questions of equity in relation to science, the initial reaction that these topics do not belong in a physics class is a reasonable one. We hope that our course and the specific discussions around representation in STEM may plant a seed and be a catalyst for students to begin to think critically, not only about the science content, but also about the role of people in the process of science.

Each semester, we make small modifications or additions to our course structure, practices, and curricula. Through this continual process of refinement, we see improvement in the percentage of students reporting a sense of belonging (Figure 1) and the positive reactions to our in-class discussions of representation (Figure 2). There are myriad factors that contribute to the overall classroom culture and implementation of the unit on equity, and we cannot disentangle them from one another. In the feedback responses included above in the "Fostering a culture of inclusion—Outcomes" section, students highlight a few specific elements of the course that they found to be useful: group work and the overall sense of community, and modifying the course based on student feedback. These elements are certainly important to the success of our course, and interact with or build on other elements described above. Though we cannot isolate individual practices or features that may have specifically impacted students' experiences in the course, we note that the collection of interconnected practices and course materials works together to create a unique class environment.

As instructors, we were initially reluctant to implement a specific unit on equity; these topics can be difficult to talk about at all, let alone in a physics classroom. Yet we have seen that it is indeed possible to foster inclusion and teach equity in our upper level physics classes. We are encouraged by the overall positive responses from students, and our own improvement through a continual process of refinement based on student results and feedback. We have presented our approach and preliminary results as a demonstration that physics and engineering educators are capable of fostering inclusion and teaching equity in upper-level classes, and that these approaches can be beneficial to students.

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