

Inclusive teaching strategies are not widely used by male physics instructorsMd Sanyat Rabby^{1,*} and Charles Henderson^{2,†}¹*The Mallinson Institute for Science Education, Western Michigan University, Kalamazoo, Michigan 49008, USA*²*The Mallinson Institute for Science Education and Department of Physics, Western Michigan University, Kalamazoo, Michigan 49008, USA*

(Received 12 December 2024; accepted 3 June 2025; published 11 July 2025)

Introductory physics is a gateway course that is required for many science, technology, engineering, and mathematics (STEM) majors. In introductory physics courses, women and racially minoritized students often have lower grades and higher attrition than white men. Inclusive teaching is widely recommended to ensure that all students have the opportunity to fully participate and succeed in the learning process. Thus, inclusive teaching practices may help increase the diversity of people in STEM majors and careers. However, these recommended inclusive teaching practices are not widely used in introductory physics courses. This study seeks to better understand the extent to which introductory college-level physics instructors use inclusive teaching strategies as well as their reasons for the use or nonuse of such practices. We conducted semi-structured interviews with 11 male instructors from a variety of higher education institutions in Michigan who taught introductory calculus-based physics courses in Spring 2022. The participants were asked to describe their use of and beliefs about 23 specific inclusive teaching strategies. Results show that few of these instructors are aware of the full range of inclusive teaching strategies. Most instructors are aware of inclusive teaching strategies that are related to active learning and frequently articulate valid reasons for implementing these strategies. However, when implementing inclusive teaching strategies, they often do not do so in ways that are known to be most effective. Instructors are less aware of and less willing to use inclusive teaching practices that require acknowledging differences in students' identities. Their reasoning is that physics is an objective science that has nothing to do with race, gender, or other aspects of identity. Overall, this preliminary study suggests that significant work is needed to help introductory physics instructors understand, value, and implement the full range of inclusive teaching strategies.

DOI: [10.1103/96y2-cyf2](https://doi.org/10.1103/96y2-cyf2)**I. INTRODUCTION**

Undergraduate students come into the classroom with different cultural and family backgrounds, personalities, races, ethnicities, genders, sexual orientations, and disabilities. The fields of science, technology, engineering, and mathematics (STEM) do not represent the larger population with respect to these, and other, aspects of identity. For example, in introductory STEM courses, the enrollment rates of Black and Hispanic students are significantly lower than their White and Asian counterparts [1]. Similarly, the rates of undergraduate STEM degree

attainment for many minoritized groups are significantly lower than for their majority counterparts [2].

The field of physics is one of the least diverse of the STEM fields. Statistics on diversity in physics show that the percentage of women and racialized minority students who receive undergraduate physics degrees is lower than nearly all other STEM fields [3]. While many students leave physics and other STEM fields prior to college, there is also significant attrition that happens during the college experience. For example, nearly half (48%) of students who entered STEM bachelor's degree programs between 2003 and 2009 had left the fields by 2009 [4]. Some of them (28%) moved to non-STEM fields, while the others (20%) left the college without a degree [4]. Black/African American students left STEM majors at higher rates than other students [4]. An important contributor to these high attrition rates for both majority and minority students is poor teaching in the core introductory STEM courses [5].

Inclusive teaching is a broad term describing instructional approaches that seek to address these problems and support more equitable course learning outcomes

*Contact author: mdsanyat.rabby@wmich.edu†Contact author: charles.henderson@wmich.edu

Published by the American Physical Society under the terms of the [Creative Commons Attribution 4.0 International license](https://creativecommons.org/licenses/by/4.0/). Further distribution of this work must maintain attribution to the author(s) and the published article's title, journal citation, and DOI.

and persistence toward STEM degrees. Inclusive teaching is about embracing student diversity in all forms, including race, ethnicity, disability, gender, ideology, socioeconomic background, level of understanding, and personality traits [6]. Inclusivity is the practice of including people across differences which implies an intentional practice of recognizing and working to mitigate biases that lead to marginalization or exclusion of some people [7]. Importantly, inclusive teaching is not only beneficial for minoritized students but also has positive impacts on all types of students [7–9]. However, inclusive teaching practices can be challenging for instructors to use for a variety of reasons [10,11]. We do not know much about the knowledge and attitudes instructors have toward the use of inclusive teaching practices since these have not been well studied.

In this study, we interviewed male instructors of introductory physics courses to understand their beliefs, knowledge, and practices related to inclusive teaching. The interview questions focused on a set of 23 inclusive teaching strategies developed from an analysis of three published overviews of inclusive teaching practices [6,7,12]. We were particularly interested in understanding these instructors' perceptions of the barriers and affordances to the use of these inclusive teaching strategies.

II. REVIEW OF THE LITERATURES

In this section, we summarize important aspects of the literature related to inclusive teaching that are relevant to this study. In the first subsection, we briefly describe perspectives on inclusive teaching and discuss how we used three key references to identify the 23 inclusive teaching strategies that we focus on in this study. In the second subsection, we focus on publications that describe the types of impacts that the use of inclusive teaching has on student grades, attrition rates, and sense of belonging. In the third subsection, we discuss research on factors that influence instructors' use of evidence-based teaching in general. Finally, in the fourth subsection, we focus on the few prior studies of instructors' beliefs about and use of inclusive teaching strategies.

A. What is inclusive teaching?

Inclusive teaching is a broad term for teaching approaches that aim to intentionally create an equitable learning environment for all students regardless of their backgrounds, identities, or abilities [7,9,13,14]. Inclusive teaching increases underrepresented students' sense of belonging in the classroom [15], which significantly impacts their motivation and, ultimately, performance [16,17]. While most articles related to inclusive teaching strategies discuss inclusive teaching in more holistic or philosophical terms, in this study, we sought to operationalize inclusive teaching in terms of specific practices that an instructor might engage in.

For this study, we developed a list of 23 specific inclusive teaching practices based on three published overviews of inclusive teaching [6,7,12]. These overviews were chosen because they were written with an audience of instructors in mind and described both the general philosophy behind inclusive teaching as well as specific inclusive teaching practices that fit within that philosophy. While each overview has its own perspective about inclusive teaching and its own set of recommended strategies, there is, nonetheless, significant overlap among the recommended inclusive teaching practices.

According to Dewsbury and Brame [7], “inclusivity is the practice of including people across differences, and we assert that inclusivity implies an intentional practice of recognizing and working to mitigate biases that lead to marginalization or exclusion of some people” (p. 1). The authors described four basic aspects of inclusive teaching: (a) developing self-awareness to remove the self from the learning process (b) learning students' backgrounds to develop empathy (c) developing an inclusive environment in the classroom, and (d) fostering inclusivity through pedagogical choices. They also argued that inclusive teaching is a philosophy that influences an instructor to implement inclusive pedagogical techniques. The authors present and describe many evidence-based practices that serve as a resource for instructors who wish to become more inclusive, particularly in addressing differences in race, ethnicity, and gender.

Sathy and Hogan [6] note that undergraduate students come to the classroom with a wide variety of experiences, cultures, abilities, skills, and personalities. A teacher's job is to help all students learn the target content and skills. The authors suggest three key principles of inclusive teaching. First, inclusive teaching is a mindset, not a list of tasks. For every decision about teaching, we should ask ourselves, “Who is being left out?” Second, the more structure, the better for all students. Structure can be added to the syllabus, assignments, tests, and pedagogy to support more equitable outcomes. Third, inclusive teaching methods should not focus on “weak” students over “strong” students but rather should be designed to better support all students. This article also offered specific suggestions for implementing these three key principles to design more inclusive courses.

Tanner [12] does not use the term “inclusive teaching,” rather she uses the term “equitable teaching.” According to Tanner, equitable teaching is about teaching all students in the classroom. It is not just for those students who are already engaged or already participating. It allows all students to verbally participate, pose ideas, take time to think, and feel welcomed. Although primarily aimed at biology instructors, these strategies are also relevant to other STEM disciplines. She presented many specific teaching strategies that promote student engagement and cultivate equity in the classroom, organized into five

TABLE I. Inclusive teaching strategies. These strategies are synthesized and organized by Sathy and Hogan [6], Dewsbury and Brame [7], Tanner [12]. “X” represents the article includes that strategy. Each has a short name followed by a slightly longer description.

	Synthesized inclusive teaching strategies	Inclusive teaching strategy present in		
		Tanner [12]	Sathy and Hogan [6]	Dewsbury and Brame [7]
1	Wait time: After posing a question pause for several seconds before soliciting verbal responses from students.	X		X
2	Interact with students: Create opportunities to interact with students on a personal level. For example, through short conversations before class or sending a quick email.		X	X
3	Timely feedback: Provide feedback in a timely fashion.			X
4	Use names: Learn and use students’ names.	X	X	X
5	Praise with caution: Praise student responses with caution, so that other students feel they still have something to add.	X		
6	Respectful climate: Develop a positive and respectful classroom climate. For example, by demonstrating warmth, respect, and interest for the students.			X
7	Solicit multiple responses: When asking a question, solicit verbal responses from multiple students without immediate judgment.	X		
8	Pre- and post-class assessment: Assess students before and after the class. For example, a vocabulary quiz before class and a short essay after class.		X	
9	Promote collaboration: Enhance cooperation and reduce competition among students.			X
10	Open-ended questions: Ask open-ended questions during class.	X		
11	Share own difficulties: Acknowledge that learning is difficult and share some of your own difficulties.		X	
12	Learn about racism and sexism: Educate yourself about the history of racism and sexism within higher education.			X
13	Low stake assessments: Use more low-stake assessments and fewer big tests.	X	X	X
14	Think-pair-share: Use “think-pair-share.” After posing a question, allow students time to think, then talk with nearby peers, and then share with the whole class.	X		X
15	Survey students: Survey students to find out how they think the course is going.		X	
16	Ensure everyone’s participation: Ensure that all students participate during class. For example, by allowing anonymous participation, using random calling, or inviting students to participate who do not volunteer regularly.	X	X	
17	Learn about the culture of higher education: Educate yourself about the cultures and norms of higher education that shape students’ experiences.			X
18	Small group work: Use structured small group activities where you provide clear instruction about the task, explicitly discuss how to participate in a group, and assign and rotate roles.	X	X	X
19	Culturally diverse examples: Integrate culturally diverse and relevant examples.	X		X
20	Share pronouns: Share your pronouns.		X	
21	Understand students’ backgrounds: Carefully understand your students within their sociocultural and institutional contexts.			X
22	Explain your teaching practices: Be explicit about your inclusive teaching practices and why you use them.	X		
23	Share your positionality: Write a positionality statement and share it with your class, for example, on the syllabus.			X

categories: (a) giving students opportunities to think and talk, (b) encouraging, demanding, and actively managing the participation of all students, (c) building an inclusive and fair classroom community for all students, (d) monitoring instructors' own and students' behavior to cultivate divergent thinking, and (e) teaching all the students in the classroom.

We synthesized specific strategies from Sathy and Hogan [6], Dewsbury and Brame [7], and Tanner [12] to develop a list of recommended inclusive teaching strategies shown in Table I that we used in the interviews. Most of the strategies are common across more than one of these articles.

B. What is the evidence that inclusive teaching strategies work?

Each of the three overviews we discussed in the previous section backed up their recommended strategies (Table I) by providing empirical and/or theoretical evidence of efficacy. Inclusive teaching is a relatively new way of thinking about teaching practices, and thus, there is not yet a shared overarching model or conceptual framework for inclusive teaching practices. Because of this, we have chosen to focus our unit of analysis on the level of discrete inclusive teaching strategies. The effectiveness of some of the recommended strategies has been well established, while the evidence base for others is more preliminary.

For readers seeking more details about the state of evidence behind the inclusive teaching strategies examined in this study, we recommend the three overview articles [6,7,12]. In the remainder of this section, we provide readers with some examples that exist in support of the recommended inclusive teaching strategies. First, we note that many, but not all, of the inclusive teaching strategies shown in Table I would fall under the category of active learning strategies, for example, wait time (strategy 1), think-pair-share (strategy 14), and small group work (strategy 18). It has been well established that active learning instructional strategies increase student content learning [18], increase exam scores, and reduce failure rates of all students on average [19,20]. These studies also show that, in many cases, active learning can have a greater positive impact on minoritized students than on the majority of students. In the following paragraphs, we focus on two specific studies that provide examples of the efficacy of inclusive teaching practices that go beyond the use of active learning. The first example study integrated culturally diverse examples (strategy 19) into a physics course and tested various learning outcomes [21]. It showed that some inclusive teaching interventions enable students to see themselves as people who do physics. The second example study found that when instructors learn and use student names (strategy 4), students feel more valued and motivated [22].

Getty *et al.* [21] examined how incorporating inclusive teaching strategies benefits all students and contributes to a more diverse physics community by reducing attrition,

especially for women. They used an experimental design in two sections of a semester-long introductory physics course. In the experimental section, the researchers incorporated diverse cultural examples (our strategy 19) that highlight the accomplishments of women physicists. After the midterm and before the final, both treatment and control students were asked to write their own physics problems involving real-world scenarios. The researchers found that women were more present in the scenarios in the treatment section than in the control section, regardless of the student's gender. They also found that treatment students demonstrated their understanding of physics concepts in more sophisticated and advanced ways.

Learning and using names is another inclusive teaching strategy (strategy 4). Cooper *et al.* [22] examined how the students value instructors knowing their names in an upper-level biology course. On the first day of class, each student was given a piece of colored card and instructed to create a name tent. Students were required to bring their name tents to class every day and display them on their desks. The classroom was stadium seating and was taught by two instructors. The researchers conducted pre- and postcourse surveys and interviewed the students. Students reported that they feel more valued, and they are more than just a face in the crowd when instructors know and use their names. They also reported that they feel more comfortable approaching instructors for help and talking broadly about topics beyond course materials. Karabenick [23] found that students who are willing to seek help from their instructors, especially in large lecture classes, tend to be more motivated and perform better on exams. Therefore, Cooper *et al.* [22] argued that using student names will likely influence student performance.

These two example studies illustrate that the use of evidence-based inclusive teaching strategies can positively influence students' motivation and sense of being included in the classroom, which, in turn, can positively influence their performance. In the following section, we will focus on reviewing literature about the factors that influence instructors' decisions regarding the use of evidence-based teaching practices.

C. What shapes instructors' teaching practices?

Instructors' teaching practices reflect both their individual characteristics and the characteristics of their instructional situation. There is also often overlap and interplay between these two types of characteristics.

Henderson and Dancy [24] generated ideas about why evidence-based strategies are not widely implemented in typical instructional situations. They hypothesized a relationship between instructional practices and factors that influence the choice of those practices. The authors categorized instructional practices into two main categories: alternative instruction and traditional instruction. Alternative instructional practices are things like active

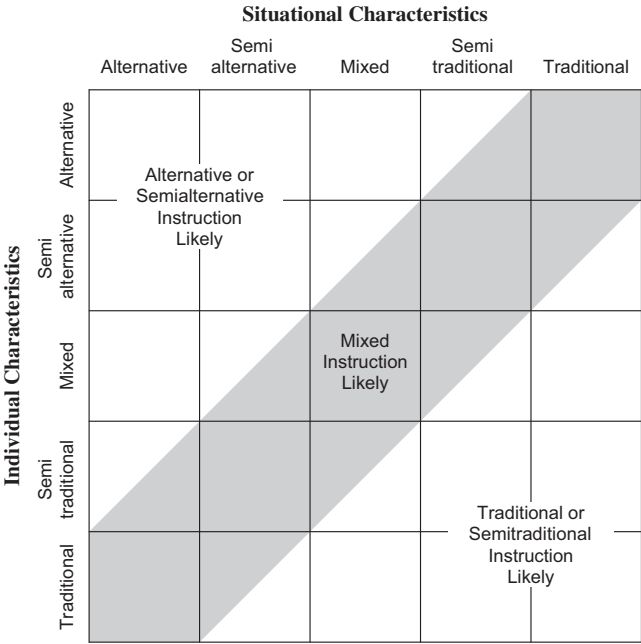


FIG. 1. A model of the instructional behavior of an individual based on situational and individual characteristics (From Henderson and Dancy [24]).

learning that have been shown to support student learning. Traditional practices are characterized largely by traditional lecture-based instruction. After interviewing physics instructors, the authors found that instructors’ use of instructional practices is influenced by a combination of situational and individual characteristics. Situational characteristics include expectations of content coverage, lack of instructor time, departmental norms, student resistance, class size, and room layout. Instructors’ individual characteristics include instructors’ conceptions about teaching practices, such as beliefs, values, knowledge, etc. The authors proposed a model (Fig. 1) to explain how individual and situational characteristics are related to instructional practices. According to the model, an alignment of individual and situational factors in the alternative direction most likely results in alternative instructional practices.

Jackson and Wenderoth [25] studied factors that influence the implementation of evidence-based teaching practices by interviewing STEM faculty who participated in a two-year professional development program, Consortium for the Advancement of Undergraduate STEM Education (CAUSE). CAUSE had an *exploration* phase that increased the awareness of evidence-based teaching practices and an *implementation* phase that provided practice and feedback on change to teaching (p. 145). Similar to Henderson and Dancy [24], they identified two basic types of factors, extrinsic and intrinsic, that influence faculty use of evidence-based teaching practices. Extrinsic factors, such as situational characteristics, are related to the context of the classroom, such as classroom layout and technology, students’ unique needs, fixed curriculum, and variation and

adaptation of strategies. For example, classroom technology influenced instructors to shift to active learning practices. Whereas intrinsic factors, such as individual characteristics, are related to instructors’ experiences and motivation—including implementation difficulties, participation in professional development, satisfaction with their current practice, and respect for students’ interests, concerns, and anxieties. For instance, some instructors had concerns from their previous implementation that an evidence-based strategy, such as random calling, may induce anxiety among students.

In summary, to understand instructors’ use of inclusive teaching practices, it is important to understand both their individual beliefs and values related to inclusive teaching as well as their understanding of the situational affordances and constraints for the use of inclusive teaching.

D. Instructors’ knowledge, beliefs, and experiences of inclusive teaching

Despite the many recommendations for the use of inclusive teaching strategies, there have not yet been many studies related to instructors’ knowledge of or beliefs about the use of inclusive teaching strategies in undergraduate science courses. There is also limited empirical evidence about whether instructors are implementing inclusive teaching strategies. There have, though, been some studies of inclusive teaching in college-level science courses. We briefly summarize them here.

Addy *et al.* [10] sought to identify the influential factors that support and impede the use of inclusive teaching in U.S. higher education. They surveyed 214 faculty from 44 different academic disciplines, including STEM and non-STEM. Survey questions focused on instructors’ self-reported knowledge about inclusive teaching as well as barriers and affordances to the use of inclusive teaching. They found that key factors predicting the use of inclusive teaching are knowledge of inclusive teaching, participation in educational development, support by the department, and being a non-STEM discipline. According to the survey results, STEM instructors reported having heavy content coverage requirements, large class sizes, and other situational constraints. They also found that the barriers to inclusive teaching efforts were either personal or institutional. Personal barriers included fear, lack of awareness, reluctance to change, and lack of responsibility. Institutional barriers included a lack of professional development on the awareness about inclusion, inadequate proper resources and lack of incentives, and limited opportunities for discussion. Unlike our study, Addy *et al.* [10] focused on the general term inclusive teaching rather than specific inclusive teaching strategies.

Instead of specific barriers and affordances, Aragón *et al.* [15] focused on instructors’ overall ideologies about diversity (colorblindness vs multiculturalism) to understand their use of inclusive teaching practices. According to the

colorblindness ideology, everyone should receive equal treatment, opportunities, and outcomes regardless of their differences. On the other hand, the multiculturalism ideology acknowledges that differences between people exist and that it can be appropriate to treat people differently based on their differences. Using surveys with instructors in STEM and closely related fields, they found that instructors with both colorblindness and multiculturalism ideologies have the intention to adopt inclusive teaching practices and the desire to be fair to traditionally disadvantaged groups of students. However, the implementation of inclusive teaching highly depended on their personal ideologies; those with a higher endorsement of colorblindness ideology implemented fewer inclusive teaching practices, and those with higher endorsement of multiculturalism ideology implemented more inclusive teaching practices. Similarly, Russo-Tait [26] used interviews with STEM faculty to conclude that most have a colorblind ideology and that this is a barrier to their successful implementation of inclusive teaching practices. These findings encouraged us to delve deeper into the knowledge and use of specific inclusive teaching strategies by instructors.

III. RESEARCH QUESTIONS

We are not aware of any prior study specifically on introductory physics instructors' perception and implementation of inclusive teaching. This study is particularly focused on understanding what physics instructors think about specific inclusive teaching strategies. We also wanted to understand their experiences using inclusive teaching strategies.

1. To what extent do physics instructors implement inclusive teaching strategies in introductory physics?
2. What factors do physics instructors identify as supporting or impeding their use of inclusive teaching strategies?

IV. RESEARCH DESIGN AND METHODS

A. Research design

To answer our research questions, we interviewed physics instructors about their ideas and experiences with 23 inclusive teaching strategies identified from the literature (see Table I). We used thematic analysis to analyze the qualitative data from the interview transcripts. Thematic analysis is a commonly used method for analyzing, reporting, and identifying patterns within qualitative data [27–30]. We closely examined the data to identify common themes that appeared within the statements made by the instructors.

B. Research methods

1. Participants

We focused our study on instructors of calculus-based introductory physics courses. This course is a requirement

for many STEM majors and, thus, a student's experience in this course can play a significant role in their decision to stay in a STEM major [31].

We focused the study on college-level physics instructors in the state of Michigan who were teaching introductory calculus-based physics in Spring 2022. We chose to limit the study to a single state since institutional student demographics can vary by state and may have an influence on instructors' knowledge about and use of inclusive teaching. To identify eligible instructors, we first used the Internet to develop a list of all two- and four-year colleges and universities in Michigan. We then used institutional websites to identify whether a calculus-based introductory physics course was offered in Spring 2022. If so, we further used the website to collect the names and email addresses of the relevant instructor(s).

Considering the time constraints and possible unique opinions about the reasons that support or impede the use of inclusive teaching strategies, we aimed for 15 to 20 interviewees [32]. Email invitations for one-hour virtual interviews were sent to a total of 79 instructors from 32 institutions in early Summer 2022, with up to two follow-up emails for nonresponders. No reimbursement, compensation, or incentives were offered for participation, and all instructors who accepted the invitation were interviewed. Although we did not have any gender-based exclusion criteria when sending out the invitation, all the instructors who agreed to participate in this study were male. The final interview sample consisted of 11 male physics instructors from 11 different institutions (see Table II). The table shows that there is diversity in participants in terms of teaching experiences, diversity of students, and classroom settings. While the number of participants was somewhat lower than our target, we did stop getting new results by the end of the interviews, indicating that saturation likely had been reached.

2. Data collection procedure

Following approved procedures from the Western Michigan University Institutional Review Board, each participant was interviewed through a one-on-one video call using the online platform Webex. Each interview was conducted by the first author and was audio and video recorded. The interview protocol is shown in the Appendix A.

The interview started with general questions about the description of their classroom setting and the demographics of their students. Then instructors were asked, "What opportunities have you had to learn about instructional strategies for teaching introductory physics? Afterward, we moved on to questions about their beliefs and use of inclusive teaching strategies. Instructors were introduced to the concept of inclusive teaching and asked if they were familiar with it. The strategies from Table I were presented over the computer screen and instructors were asked to rate the extent to which they use each of the 23 inclusive

TABLE II. Teaching profiles. All the participants were male. Their class size is considered small if it has 35 or fewer students, and large if it has more than 35 students.

Participants	Participants' institution type at the time of interview	Years of teaching experience	Years of teaching experience in introductory calculus-based physics course	Participants' self-reported description of the diversity of students in their introductory calculus-based physics courses	Class size	Class layout
Participant A	Doctoral/Professional University	9	5	90% male, 10% female, 90% White, non-Hispanic,	Small	Fixed seating
Participant B	Associate College	7	6	80% male, 20% female, 60% White, 20% Asian, 20% Latino and African American,	Information not available	
Participant C	Associate College	40	40	75% male, 25% female, 25% Hispanic, 15% Black,	Small	Moveable chairs
Participant D	Research University	25	20	20% male, 80% female, 20% African American, and some Eastern European	Large	Fixed seating
Participant E	Associate College	26	26	50% male, 50% female, 10% African American	Small	Online
Participant F	Baccalaureate College	3	3	70% white, 30% other races	Large	Fixed seating
Participant G	Baccalaureate College	16	6	50% male, 50% female, 5% African American, 5% Asian, Mostly white	Small	Fixed seating
Participant H	Baccalaureate College	16	12	60% females, 40% male, 5% African Americans, 5% Asian students, mostly native Americans	Small	Moveable chairs
Participant I	Associate College	24	24	Mostly male students	Small	Fixed seating
Participant J	Baccalaureate College	37	27	50% male, 50% female, a lot of students of color, a few Asian American, small numbers of African American, some Native Americans	Small	Moveable chairs
Participant K	Research University	20	7	20% male, 80% female, 4% African American, some international students	Large	Fixed seating

teaching strategies. Instructors reported the use of each strategy according to a scale from 0 to 4; not at all descriptive of my teaching (0), minimally descriptive of my teaching (1), somewhat descriptive of my teaching (2), mostly descriptive of my teaching (3), very descriptive of my teaching (4).

When the instructor said they used a strategy they were asked follow-up questions. For example, “how do you use that?,” “does the whole class do that?,” “do only some students do that?,” “why do you think this is important?,” “what might be the benefits of using it more?,” “do you encounter any difficulties with the higher use of this strategy?,” “When an instructor stated they did not use a strategy, they were asked follow-up questions. For example, “why don’t you use this?,” “why don’t you use it more?,” “do you think it would be helpful for students if you used it more?,” “have you ever thought about using it more?,” “what are your concerns about using it?,” and “what would be the

pros and cons of using it more?” Not all follow-up questions were asked for every strategy. The follow-up questions and their wording were adjusted to fit each strategy because the structures of the strategies are not always parallel. For example, in “learning about racism” (strategy 12), we did not ask, “Does the whole class do that?” Instead, we asked, “How do you approach learning about racism?” Each interview ranged from 60 to 120 min with a median of 80 min. Near the end of the interview, instructors were asked to describe their overall impression of inclusive teaching.

3. Data analysis

The online meeting platform Webex was used to transcribe the interviews, and then we manually labeled and organized the transcripts to facilitate analysis. Each interviewee was given a pseudonym, Instructor A, Instructor B, etc. Excel software was used to organize transcribed text,

codes, and themes. The first phase of the thematic analysis involved going through each interview and, for each of the 23 instructional strategies, extracting (1) their self-reported rating of use and (2) the exact text of their responses to questions of “why is this strategy important or not important?” “do you encounter any barriers when you use it?” “if you use it, why do you use it?” “if you do not use it, why don’t you use it?” “do you want to use it in future?” and “do you want to use it more in future?”

In the next phase, we quantified the data that consist of Yes, No, and To what extent regarding the use of the strategies and the frequency of use on the Likert scale. Then, using thematic analysis, we extracted the reasons for use and lack of use from the responses to interview questions. We first grouped each reason in our priori categories as either an affordance or constraint. Within the affordances, we then developed emergent categories to capture the latent themes related to the meaning of each reason. We followed the same procedure for the constraints. Categories and example interview quotes are shown in the results section.

Instructors were also asked, “How do you use this strategy in your classroom?” We analyzed their description to help triangulate their self-reported ratings. This analysis was to understand to what extent inclusive teaching strategies are actually being used.

4. *Validity and trustworthiness*

To develop a strong interview protocol, the interview was pilot tested on three instructors with a range from low to high prior experience with inclusive teaching [33]. Their feedback was used to make revisions to the interview protocol questions and their terminologies. The goal was that the protocol would work with participants who were familiar with inclusive teaching strategies as well as those who were not.

Another main purpose of the pilot test was to adjust the time required for the interview. The primary objective of the interview protocol was to identify instructors’ utilization, comprehension, and experiences with 23 inclusive teaching strategies. We wanted to make sure that any physics instructor could respond to the interview questions and that the interview could be completed in approximately 1 h.

The first author conducted all the interviews. He then read the transcripts and watched the recorded videos multiple times to familiarize himself with the interview responses and develop codes. He wrote memos for each interviewee’s response to each strategy. The authors met regularly to discuss coding, cross-examine the memos, codes, and transcripts, and refine ideas. We discussed disagreements related to interpretations and coding until an agreement was reached. During the analysis, we also sought external feedback. We made multiple interactive presentations at the Mallinson Institute for Science Education research group meetings and received feedback on our ideas and procedures. This research group consists of faculty and graduate students who are doing

research in science education. The preliminary findings were also presented at the American Physical Society’s national meeting in April 2022 and feedback was used to further sharpen the findings.

V. RESEARCHER POSITIONALITY

M. R. is an international Ph.D. student at Western Michigan University (WMU). I identify my race as Asian. I am male. I am teaching introductory-level classes, and I work as a physics education researcher. I am 37 years old, and I spent the last 5 years of my life in the United States. I grew up in a culture where human skin color is not an issue in academia, but where gender is a big issue; both society and academia are strongly dominated by males. I never knew about physics education research before coming to the US, and I never personally strongly dealt with the terms related to race, gender, self-identity, and so on. However, there were many times when, as a student, I felt I was not included in the classroom, I was not being heard, and I was not important in the class. That is why I got interested in doing research on inclusive teaching. I believe that now I am more aware of identity-related issues and sense of belonging in the classroom in the United States. My mindset positively changed the most over the weekly meetings with my supervisor and throughout the analysis process.

C. H. has been a physics professor at WMU for 23 years. I hold many privileged identities: white, male, straight, well educated, and middle class. Through my professional and personal life, I have been exposed to ideas related to societal biases, racism, sexism, and other ways that certain types of people are excluded from full participation in many aspects of education and other areas. I attempt to use inclusive teaching practices in my own instruction, and I have been involved in several prior research projects related to equity, identity, and belonging. I have also engaged in prior research studies focused on physics instructors’ use of and beliefs about various teaching strategies.

VI. LIMITATIONS OF THIS STUDY

As with all research, this study has several limitations. First, this was an interview-based study. Parts of the interview asked instructors to self-report their instructional practices, which may not accurately reflect their actual instructional practices. Interviews are a good way to identify instructor conceptions; however, their actual practice would likely be better understood through a research design combining multiple methods, such as interviews, observations, and artifact analysis [34–36]. Another possible limitation is the generalizability of the findings. The number of participants ($N = 11$) is relatively small. And, participants were all from the state of Michigan, which has less diversity than many states. Instructors working at institutions with more diversity, such as Hispanic serving institutions, might have different experiences with and conceptions about inclusivity and inclusive teaching. In addition, all participants are male.

Although the invitation was sent out to all instructors who were teaching an introductory calculus-based physics course in Michigan in Spring 2022, no female instructors responded. Statistics from the American Physical Society (APS) show that 19% of college physics faculty were female in 2018 [37]. We also know that female faculty are more likely to use innovative teaching methods [38]. Thus, having female participants would have been desirable. Future research may need to develop additional recruitment methods to encourage participation by female physics faculty.

VII. RESULTS

A. RQ.1. To what extent do physics instructors implement inclusive teaching practices in introductory physics?

1. High use vs low use inclusive teaching strategies

At the beginning of the main part of the interview, for each of the 23 inclusive teaching strategies, instructors were asked, “To what extent do you use this strategy?” Instructors used the Likert scale (Table III) to self-report their level of use of each strategy. They were then asked to explain why they chose that level of use.

Based on the instructor’s self-reports, we categorized each strategy as high, medium, or low use. High use strategies were those that received an average self-reported use of 3 or higher. Medium use strategies were those that received an average rating of at least 2, but less than 3.

TABLE III. The instructors used this Likert scale and self-reported their use of individual inclusive teaching strategies.

Likert scale	
0	Not at all descriptive of my teaching
1	Minimally descriptive of my teaching
2	Somewhat descriptive of my teaching
3	Mostly descriptive of my teaching
4	Very descriptive of my teaching

Low use strategies were those that received an average rating of less than 2.

Figure 2 shows the average self-reported use of each strategy by instructors. There are two claims that we can make from this figure. First, there is a wide range in the self-reported levels of use across different strategies. And, second, there is a reasonable amount of consistency among these instructors in terms of their level of use of these strategies. In later sections, we will focus on reasons why some strategies are used much less than others. However, first, we will focus on how accurate these instructors’ self-reported levels of use are likely to be.

2. Disparities between instructors’ self-reports and the actual use of the strategies

We know from prior research that self-reported levels of use of instructional strategies might not be accurate [39,40]. During the interview, after instructors rated their use of an instructional strategy, they were asked follow-up questions,

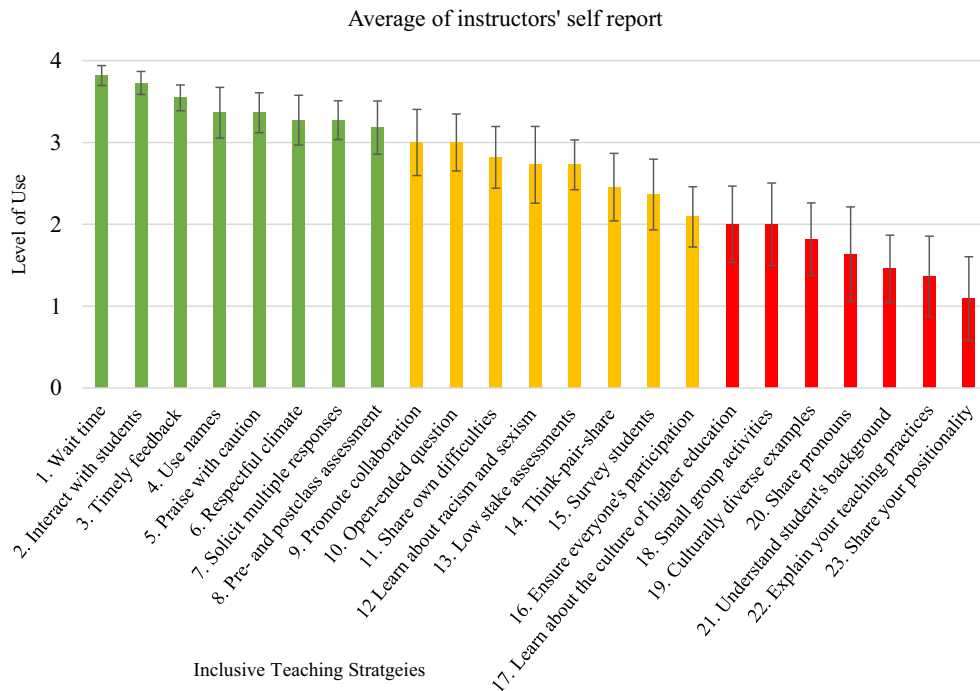


FIG. 2. The average instructors’ self-reported use score for each inclusive teaching strategy. Green bars show high use strategies (average rating of 3 or higher). Yellow bars show medium use strategies (average rating of at least 2 and less than 3). Red bars show low use strategies (average rating less than 2). Error bars represent the standard error.

TABLE IV. Examples of how researchers rated each instructor on the extent of their use of each inclusive teaching strategy.

Strategies	How the strategy should be used (from research articles)	Instructor's description of use	Researchers' judgments of instructor's use
Strategy 7: Solicit multiple responses: When asking a question, solicit verbal responses from multiple students without immediate judgment	Tanner [12] described: • To broaden participation and avoid getting response from the same students, "instructors can set the stage for this strategy by asserting, 'I'm going to pose a question, and I'd like to see at least three hands who would share their ideas. I won't hear from anyone until I've got those three volunteers.'" (p. 325). • If no one is raising a hand or the same students continually raise their hands, random calling can be a useful strategy for broadening student participation. (p. 326).	Responses of Instructor A: To what extent do you use strategy 7, (use Likert scale, 0 to 4)? <i>It's 4</i> What is your experience in using this strategy? <i>I mean, it tends to be, um, the same students. But yeah, I don't like to do random calling. Um, I might try to make eye contact with everybody and sometimes that helps. Um, if I make eye contact with somebody, they might be more likely to speak up but um, yeah.</i> Do you think ensuring participation, for example through random calling is valuable (this question was asked in strategy 16)? <i>You know, it's not that I don't want students to be uncomfortable, but I just haven't found that to be a good type of discomfort. I haven't found it to be a productive discomfort.</i>	For strategy 7, the instructor indicates that he gets mostly the same students who respond. This is in direct conflict with the goal of including many student voices in the class discussion. Also, for strategy 16, he was less interested in directly inviting students to participate, because he thinks it does not create productive discomfort for the students. For strategy 7, Instructor A reported 4 on the scale, but the researchers rated his use as 2.
Strategy 21: Understand students' backgrounds: Carefully understand your students within their sociocultural and institutional contexts.	Dewsbury and Brame [7] described: • "Dialoguing is the process by which the instructor humbly gets to know the students and their unique backgrounds." (pp. 18: fe2, 2) • "Categorizations of students into ethnic and other demographic bins have their uses and may be a useful starting point for instructors, but by themselves can serve to mask the nuances present in the students' unique stories." (pp. 18: fe2, 2)	Response of Instructor C To what extent do you use strategy 21, (use Likert scale, 0 to 4)? <i>In a broader sense of unique background, I would say, give it a 4, because I would like them to bring examples from their background into the classroom, but in terms of pinpointing them and saying, well, from your cultural perspective you know, tell us about this and that, that's probably more appropriate in maybe a sociology class or a geography class.</i>	The instructor somewhat contradicts himself in terms of valuing and using this strategy. He said he likes if his students bring examples from their backgrounds. But, he also indicates that their cultural perspectives are probably more appropriate for a sociology or geography class [as opposed to a physics class]. The instructor also does not mention any other ways that he seeks to understand students' backgrounds that could be appropriate in a physics class. For strategy 21, Instructor C reported 4 on the scale, but the researchers rated his use as 1.

for example, "What is your experience in using this strategy?" or "How successful are you in implementing this strategy?." Their responses to these follow-up questions provided insights into the extent to which each strategy is actually being used.

During our analysis, we critically examined our participants' responses to these follow-up questions with the goal of making a judgment of the extent to which we think they

are actually using each strategy as recommended. We based this judgment on how each strategy is described in the research articles we cited earlier as well as our experiences as instructors. Making these judgments involved a significant discussion among the researchers. Since we did not have complete information about how instructors used each strategy, our default was to give each instructor the highest rating that we could justify. Table IV provides a few

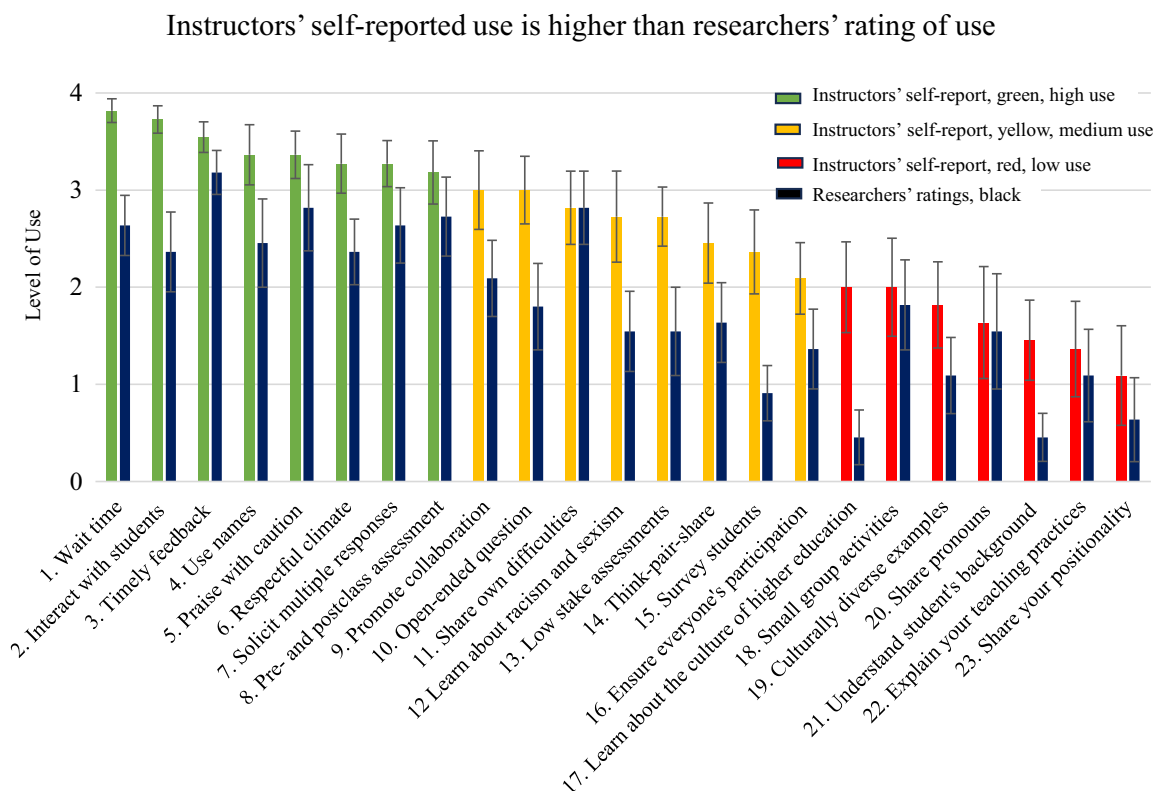


FIG. 3. This graph represents the differences between instructors' self-report and our rating of them for all strategies. Almost every instructor reported themselves higher for almost every strategy. Error bars represent standard error.

examples of instructors' self-reports vs our judgment of their level of use.

Instructors' self-reported ratings and our ratings for all strategies are shown in Fig. 3. The figure shows that instructors' self-reported ratings and our ratings rarely

matched, with our ratings almost always being lower. Also, our average ratings for instructors were higher than 3 for only one strategy, "providing feedback timely," which suggests that most of the strategies are not actually being highly used. This analysis suggests that instructors are not

TABLE V. Examples of instructors' intentions for future use when they are not fully using the strategies.

Wants to use more	Does not want to use more	Unclear about the future use
Strategy 15: Survey students. Responses of instructor A:	Strategy 7: Solicit multiple responses. Responses of instructor B:	Strategy 23: Share your positionality. Responses of instructor G:
To what extent do you use strategy 15, (use Likert scale, 0 to 4)?	To what extent do you use strategy 7, (use Likert scale, 0 to 4)?	To what extent do you use strategy 23, (use Likert scale, 0 to 4)?
<i>I would say 3. I do it once in the middle of the semester. And then they have their end of semester survey that they do anyway</i>	<i>I would say probably a 2 on my scale for how often I use it.</i>	<i>I probably want to say 0.</i>
Do you want to use it more in future?	Do you want to use it more?	Do you want to use it in future?
<i>I'll try to do it every week or every 2 weeks.</i>	<i>I think I'm happy where I'm at.</i>	<i>I should look into it. I'm wondering if I could, so. I have an inclination to limit the amount of stuff, the number of pieces of paper, I tried to keep my syllabus short and so, I, I need to think hard about what the benefits end up being if something like this</i>
What are the pros of surveying students?	Do you think that it will be valuable if you use it more?	
<i>The benefits are, um, you can really identify something you're doing that is not getting in the way of their learning that maybe you hadn't thought of. And when you get several students saying that, then it's a sign that you want to make an adjustment to help bring them along.</i>	<i>Generally, yes, but once again, it comes down to if students are actually willing to participate.</i>	

using the strategies as much as they think. We acknowledge that the researchers' ratings are subjective and based on limited information. However, consistent with prior research [40–43], these results suggest that instructor self-reports can over-emphasize their use of specific instructional strategies.

3. Instructors' intention for future use of inclusive teaching strategies

When instructors rated their use of a specific inclusive teaching strategy below 4 (very descriptive of my teaching) on the Likert scale they were asked, "Do you want to use this strategy more frequently in the future?" We categorized their responses as "wants to use more frequently in the

future" and "does not want to use more frequently in the future." Those who want to use a strategy more typically articulated the importance of the strategy and indicated they want to learn more about it to improve their use of it. Those who do not want to use a strategy more rarely gave reasons beyond simply indicating that they were happy with their current level of use. There were also, of course, some responses where instructors were not sure and indicated hesitation or uncertainty about future use. Their responses were not clear enough to be categorized as wanting or not wanting to use it more. Table V provides examples of quotes from instructors for those three categories.

The following Fig. 4 presents the number of instructors who fall into each category of intention to use in the future

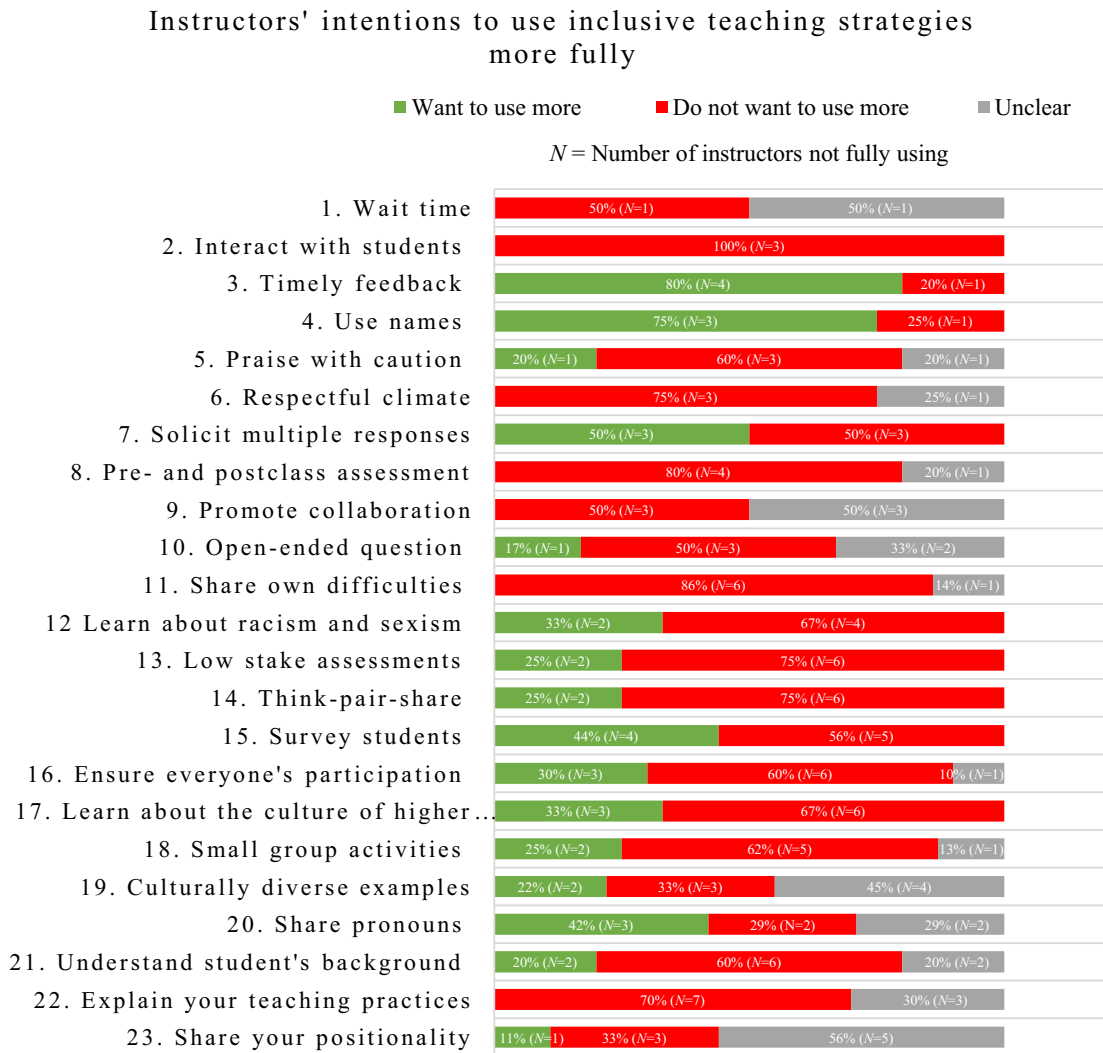


FIG. 4. Instructors' intentions to use specific inclusive teaching strategies more. Each row represents the instructors who rated their use of that strategy as less than the maximum use (4 on the Likert scale). Each row then shows, of those instructors, whether they indicated wanting to use that strategy more in the future, not wanting to use that strategy more in the future, or not giving a clear response about future use. For example, strategy 20 (share pronouns), $N = 7$ people do not fully use (reported themselves below 4 on the Likert scale), $N = 3$ people want to use more in the future (42% of 7 people), $N = 2$ people do not want to use more in the future (29% of 7 people), and $N = 2$ people are not certain about more use in the future (29% of 7 people). See Appendix C for a table with a more detailed breakdown of the data reported in this figure.

(see figure caption for details). This figure represents only those instructors who reported themselves below 4 on the Likert scale. The responses vary quite a bit across the different inclusive teaching strategies we asked about. However, the figure shows the majority of the instructors who do not already use an inclusive teaching strategy at the highest level do not want to use the strategy more in the future. For 14 of the strategies, over half of instructors do not want to use a strategy more. In contrast, there are only two strategies where more than half of the instructors indicate wanting to use it more. Instructors also shared the reasons behind their full use, different levels of low use, and nonuse. In the following section, we explore those reasons.

B. RQ.2. What factors exist that support or impede the use of inclusive teaching practices?

1. Reasons why instructors use and do not use these strategies

After instructors rated their level of use of an inclusive teaching strategy and described their use in more detail, they were asked follow-up questions about why they use the strategy to the extent they do. When they indicated that they used a strategy, follow-up questions included: “Why do you think this is important?,” “What are the benefits of using it?,” “Do you encounter any difficulties with higher use of this strategy?,” and “Why don’t you use it more?,” When instructors indicated that they made minimal or low use of a strategy, follow-up questions included: “What are the barriers or concerns about using this strategy?,” “Have you ever thought about using it more?,” and “Do you want to use it in future?” From analyzing those responses, we developed a set of emergent categories for the affordance and barriers to the use of the strategies. Tables VI and VII show each emergent category along with a definition and

example interview quote. Table VIII shows the percentage of instructors who made responses in each category for each inclusive teaching strategy.

2. The reasons for highly used strategies

The first eight strategies in the list are highly used according to instructors’ self-reports. The most common reason instructors gave for their use of these strategies is that they help students to learn the physics content. Some instructors also indicated that these strategies help to create a sense of belonging in the class. Besides benefits, instructors also experience some challenges in using these strategies. The challenges they experience are student resistance, limited time, and lack of knowledge and skills. For example, 55% of instructors said soliciting multiple responses (strategy 7) is beneficial because it allows students to think about the content. In addition, they also said most of the time students are not willing to participate and they do not know how to encourage those who regularly do not volunteer. In another example, 64% of instructors said providing feedback (strategy 3) is beneficial because it allows students to rethink and understand the content better. They also mentioned they struggle to balance their time, but if they had more time or assistance, they would provide meaningful feedback more frequently. It is also noteworthy that the instructors rated creating a respectful climate (strategy 6) as highly used, yet none of them mentioned an affordance for it. The interviewees had little to say about creating a respectful climate except that they felt they did it. We suspect that this may be because the interviewees want to think that they are creating a respectful climate even though they may not have given it much thought or attention. For example, none of the interviewees described how or why they create a respectful climate, nor did any of them offer evidence to suggest that they have been successful.

TABLE VI. Definitions with examples of affordances that support the use of inclusive teaching strategies.

Affordance	Definition	Example
Learn physics	The strategy provides more opportunities for students to think about, engage with, and learn the physics content.	Strategy 14 (Use think-pair-share), interviewee A: Why do you think this is important? <i>It slows things down and gives them time to think about their reasoning. Um, gives them time to explain their reasoning to a classmate, so it's kind of less threatening to describe it to a classmate than to me, or to the whole class.</i>
Sense of belonging	The strategy helps students feel welcomed and that they belong in the classroom.	Strategy 17 (learn your student’s culture), interviewee F: Why do you think this is important? <i>It would help the students feel more, you know, just the fact that I am reaching out to learn more about them, hopefully they would feel a more welcome and more understood which would help them learn better, I would think that they feel more of a belonged in that space.</i>

TABLE VII. Definitions with examples of barriers that impede the use of inclusive teaching strategies.

Barriers	Definitions	Examples
Student resistance	Instructors think the strategy is important for students, but they think that some students will be reluctant to participate or may even actively resist or complain.	Strategy 10 (Ask open-ended question) Interviewee B: Do you encounter any difficulties? <i>Usually, it comes down to the students. A lot of students come in going like I just want to get the answers and get out of here. I'll just be honest, sometimes they're there because they're required to be. They don't want to participate.</i>
Not for physics classroom	Instructors believe the strategy is not appropriate for use in a physics classroom.	Strategy 21 (Allow students the opportunity to share their backgrounds), Interviewee F: Do you want to use these items in the future? <i>Maybe this is not the most appropriate in the context of a physics course. I would have to think really hard about how that would make sense. Like, it is a good thing, but just because it's good doesn't mean it makes sense for a physics class for someone to do a report on, you know, this aspect of their own culture.</i>
Limited time	Instructors said the strategy is important, but it requires too much time to implement. Statements often suggest that they feel that they have to choose between using the strategy or covering the course material.	Strategy 14 (Use think-pair-share), Interviewee B: To what extent do you use this strategy in your class according to the Likert scale? <i>I say that's more of a 2 on the scale. Part of the problem I'm having with the Calc physics is the amount of material that needs to get through So, I would like to use it more, but it's a time constraint issue.</i>
Lack of knowledge and skills	Instructors said they think the strategy is/could be important but do not enough much about it. They understand the meaning, and appreciate the importance but do not know how to use it properly.	Strategy 19 (Integrate culturally diverse and relevant examples) Interviewee D: Do you think this strategy is valuable? <i>It's a worthwhile effort to try to integrate culturally diverse examples in physics. I think, in physics, it's just a nice challenge. This question made me think and I could try to do more.</i> Do you think, we can search for diverse examples personally and bring those examples in the classroom? <i>Probably yes. It's a challenge. I don't know how to do it, but I think it might be doable.</i>

3. The reasons for medium used strategies

The second set of eight strategies is medium used, according to instructors' self-reports. The main affordance that instructors mentioned is that these strategies help students to learn physics, which is the same as highly used strategies. Some instructors also note that these strategies can promote a sense of belonging. However, they do not use these strategies more frequently because they are concerned about student resistance and also feel that they lack the necessary knowledge and skills to implement these strategies successfully. For example, for asking open-ended questions (strategy 10), 36% of instructors said they did not have sufficient knowledge to do it successfully in a way that many students willingly participated. For using low-stakes assessments (strategy 13), 55% of instructors felt that this could help students learn physics. Many of these also said they need guidance to prepare meaningful low-stakes assessments. In another example, most instructors believe that think-pair-share (strategy 14) allows students to actively engage

with the material and learn physics. However, many instructors do not use this more often because they struggle with the "sharing" part. They note that students often resist sharing, and the instructors do not know better ways to invite students to share without provoking resistance. Learning about racism and sexism (strategy 12) is another medium used strategy where instructors said they try to learn as much as they can, mostly by reading literature, attending educational workshops or seminars, and discussing with colleagues. Almost all of them articulated that learning is very important because it helps them to see what is going on in physics in terms of current issues related to diversity, racism, and sexism which can help them modify their instruction. However, in terms of using it, they said mostly they do not do it intentionally and they cannot do it frequently because it requires extra time and they are already overwhelmed by other duties. Many of them also said that it is challenging for them to find good resources because it is a broad area and they are not educational specialists.

TABLE VIII. The affordance and barriers that support and impede instructors' use of inclusive teaching strategies. Shades represent the percentage of instructors in each cell: 0% as standard (not a reason), 9% as italic (niche reason, 1 person), 18%–27% bold (frequent reason, 2–3 people), and 36%–91% as bold italic (prominent reason, 4 or more people). The percentages were chosen so that nonzero cells were distributed as evenly as possible between niche, frequent, and prominent reasons.

		0%9%(18–27) %(36–91) %					
		Affordance			Barriers		
		Learn physics	Sense of belonging	Students' resistance	Not for physics classroom	Limited time	Lack of knowledge and skills
No	Inclusive teaching strategies	Percentage of instructors					
High used	1. Wait time	73	27	9	0	0	0
	2. Interact with students	36	36	0	0	0	18
	3. Timely feedback	64	9	0	0	45	9
	4. Use names	0	45	0	0	0	36
	5. Praise with caution	18	27	18	0	9	27
	6. Respectful climate	0	0	0	0	0	36
	7. Solicit multiple responses	55	27	27	0	9	18
	8. Pre- and post-class assessment	73	0	9	0	18	27
Medium used	9. Promote collaboration	45	18	0	0	0	18
	10. Open-ended question	64	0	36	9	18	36
	11. Share own difficulties	9	36	0	0	0	0
	12. Learn about racism and sexism	0	0	0	9	27	36
	13. Low stake assessments	55	9	0	9	0	36
	14. Think-pair-share	82	18	64	0	18	27
	15. Survey students	9	27	0	0	0	0
	16. Ensure everyone's participation	36	0	91	0	0	9
Low used	17. Learn about the culture of higher education	0	27	0	45	9	27
	18. Small group activities	27	27	9	0	18	27
	19. Culturally diverse examples	0	27	0	27	9	64
	20. Share pronouns	0	27	0	0	0	18
	21. Understand student's background	0	9	0	55	9	27
	22. Explain your teaching practices	0	18	0	0	0	9
	23. Share your positionality	0	9	0	0	0	64

4. The reasons for low used strategies

The third set of seven strategies is low used according to instructors' self-reports. The main reasons given for low use are that instructors do not know much about these strategies and they do not view these strategies as promoting physics learning. Some instructors explicitly said that these strategies are not relevant for physics classrooms, while others said that they do not know enough about them. For example, 7 out of 11 instructors said they do not know what a positionality statement is (strategy 23). Yet, even after the interviewer described what a positionality statement is, these instructors did not indicate an interest in using it in the future. In another example, most instructors did not think that understanding students' sociocultural backgrounds (strategy 21) is relevant in physics classrooms.

As we looked at the low-used strategies, we noticed that many of these require instructors to acknowledge the role of identity in physics teaching and learning. Figure 5 shows our listing of the seven instructional strategies that we judged to

require acknowledging identity issues. Notice that these are among the lowest used strategies of the 23 that we asked about. Hence, we hypothesize that these instructors may be reluctant to use instructional strategies that require consideration of identity issues. While only a minority of these male instructors explicitly stated that things such as students' cultures or backgrounds are not relevant in a physics classroom, most chose teaching strategies as if they believed this. We further note that none of the instructors we interviewed said anything about identity issues of race or gender even though it is well known that the field of physics lacks racial and gender diversity, and they were being interviewed about inclusive teaching practices. In addition, when we asked about strategy 21, learning about students' backgrounds, many instructors said that they did not think this would be appropriate for a physics classroom. This suggests that these male instructors may have been consciously or unconsciously avoiding thinking about identity issues with respect to their teaching, which is consistent with

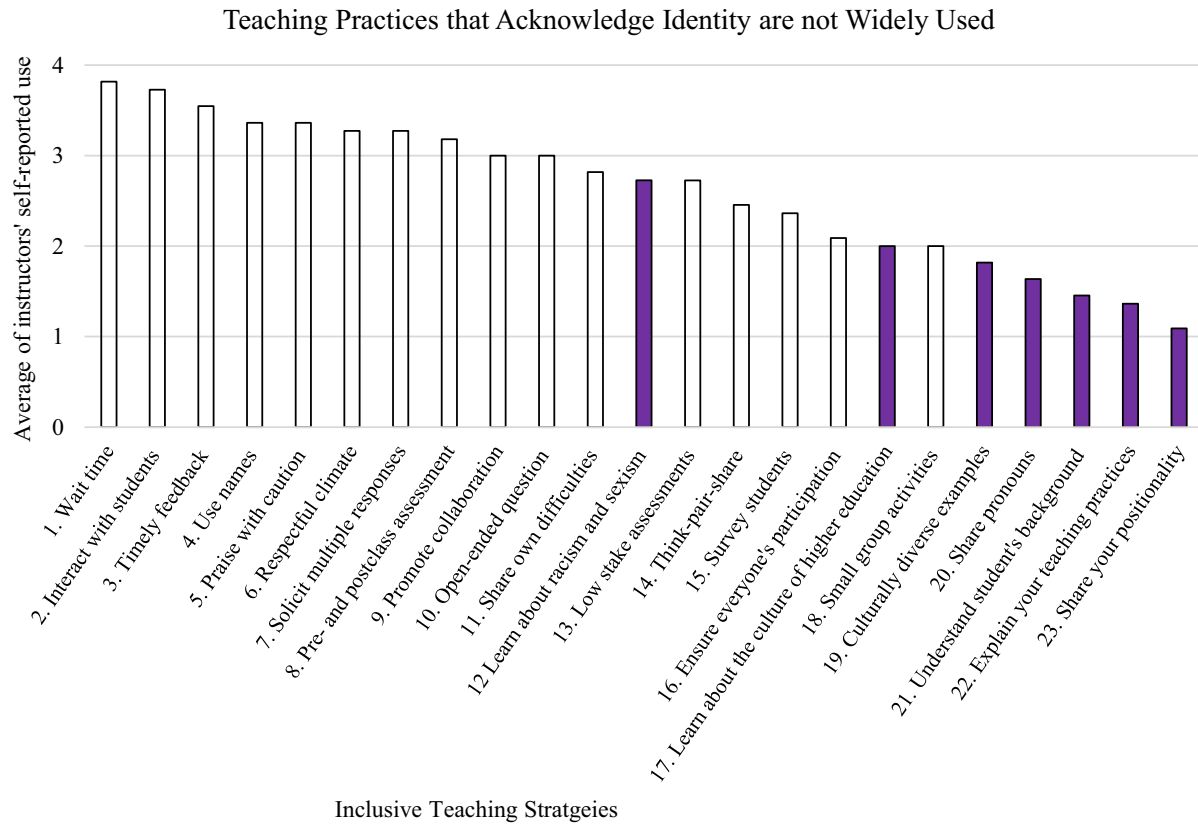


FIG. 5. The purple color or solid-filled bars are the strategies that acknowledge student identities. And most of them are low used by the instructors according to their self-report.

prior research that found instructors with greater colorblind ideology adopt fewer inclusive teaching practices [15]. It is also consistent with research suggesting that conventional teaching approaches are unintentionally exclusive to students whose identity is not traditionally represented in the classroom [44]. Future research is needed to better understand this issue. This is also an aspect of this study where female instructors may have responded differently than male instructors.

VIII. CONCLUSIONS

A. RQ.1. To what extent do physics instructors implement inclusive teaching practices in introductory physics?

1. Instructors do not make use of the full range of inclusive teaching strategies

During the interview, we asked instructors to self-report their level of use of 23 inclusive teaching strategies. Based on their self-reported levels of use, we rated the strategies as high use (wait time, interacting with students, timely feedback, using names, praising with caution, respectful climate, soliciting multiple responses, and pre- and post-class assessments), medium use (promote collaboration, open-ended question, share own difficulties, learn about racism and sexism, low stake assessments, think-pair-share,

survey students, and ensure everyone's participation), and low use (learn about the culture of higher education, small group work, culturally diverse examples, share pronouns, understand student's background, explain your teaching practices, and share your positionality).

Overall, we can conclude that these instructors do not make use of the full range of inclusive teaching strategies. They systematically use some types while avoiding other types. For example, many of the highly used inclusive teaching strategies are various forms of active learning. While many of the lower-used strategies require acknowledging student identities.

2. Instructors do not use inclusive teaching strategies as much as they think they do

After self-reporting their level of use of each strategy, we then asked the instructors to describe a bit about how they use each strategy. Based on their responses we were able to provide our own rating of their level of use of each strategy. As shown in Fig. 3, in every case except for one, our rating was lower, sometimes much lower, than their self-reported rating. This is consistent with prior studies that found instructors often overestimate their use of research-based instructional strategies [42,43]. This gives further support to our conclusion that instructors do not make use of the full range of inclusive teaching strategies.

3. Instructors are not very interested in using more inclusive teaching strategies

When instructors rated their use of a strategy below the highest level of use (that is, below 4 on our Likert scale), they were asked, “Do you want to use this strategy more frequently in the future?” Most instructors were not interested in doing so. So, while they value the inclusive teaching strategies that they are using, they are generally happy with their current level of use. For example, several instructors said that they are using small group activities (strategy 18) sometimes, but they do not want to do it more frequently. For the strategies that they already use but use less frequently, they do not intend to increase their usage. Additionally, instructors generally do not plan to adopt strategies they have never used. For example, most instructors do not explicitly talk about inclusivity (strategy 22) at all nor do they have any plans to start doing so.

There were some exceptions to this trend of not wanting to use inclusive teaching strategies more. Many instructors noted that they want to increase their use of some strategies: provide timely feedback (strategy 3), use names (strategy 4), and solicit multiple responses (strategy 7).

In summary, our answer to research question 1 is that most instructors say they value many inclusive teaching strategies. However, they do not fully use many of these strategies. And, they are generally happy with their current level of use.

B. RQ.2. What factors exist that support or impede the use of inclusive teaching practices?

1. Instructors place significant value on instructional strategies that help students learn physics

Instructors described the benefits of and reasons for using inclusive teaching strategies. We categorized these into two major affordances: helping students learn physics and enhancing students’ sense of belonging.

The key factor that motivates instructors to use any of the inclusive teaching strategies is that they believe it helps students learn physics content. Instructors also use inclusive teaching because they believe it might help to enhance students’ sense of belonging. But this factor plays a smaller role in their instructional choices.

2. Instructors say that their lack the knowledge and skill and lack of necessary time inhibit the use of all types of inclusive teaching strategies

Instructors also described their concerns about and reasons for not using inclusive teaching strategies. We categorized these into four major barriers: student resistance, not for the physics classroom, limited time, and lack of knowledge and skills. The key barrier that instructors noted that impedes the use of nearly all strategies is that instructors lack the necessary knowledge and skill to use the strategies. For example, many instructors said that they value using culturally diverse examples (strategy 19), but they are not always

aware of many diverse examples. They said that they need resources with diverse examples because the textbooks do not have many. For another example, instructors appreciate the importance of using names (strategy 4), but they cannot remember names when they have large classes and are not aware of better ways to remember large numbers of names. Writing a positionality statement (strategy 23) is another example, where most instructors indicated they were unfamiliar with the concept and expressed doubts about its importance as a teaching strategy.

Time is another challenge for instructors. They consider implementation of some of the strategies as requiring additional work and they do not think that they have sufficient time for this. For example, they want to provide feedback timely (strategy 3) before starting a new topic and they want to provide more extensive feedback with longer explanations, but they do not have enough time to do so. In addition, some instructors said that finding enough time is the main barrier for them to learn about racism and sexism in higher education (strategy 12). In addition to their personal workload, some instructors also talked about limited class time. They noted that their course includes an overwhelming amount of content, and their priority is to cover this content. For example, they said they wish to ask open-ended questions (strategy 10) and solicit multiple responses (strategy 7) more frequently, but doing so limits the content that they can cover in a class session, and they do not think that they can do that. Addy *et al.* [10] also found similar challenges; they identified a lack of knowledge and skills as a key individual barrier, while limited time was noted as a key situational barrier restricting instructors’ use of inclusive teaching.

Not having sufficient time, skills, or knowledge are very common barriers that instructors provide for not incorporating many types of teaching strategies [10,25,45]. Henderson and Dancy [24] classified instructors’ lack of time as a situational barrier. And they classified the lack of skills and knowledge as individual barriers. While instructors may indicate that they value these strategies, their lack of willingness to spend time looking for resources or developing the necessary knowledge suggests that implementing these strategies is not a particularly high priority for them. This explanation that implementing inclusive teaching practices is not a high priority is also consistent with Fig. 4 which shows that many instructors are not interested in using most strategies more than their current low use. This is consistent with the results of Petersen *et al.* [46] who argued that traditional instructors inherit a mindset of conscientious instruction that prioritizes explicitly covering all of the course material and that this mindset often prevents consideration of alternative forms of instruction.

3. Instructors worry about students’ active participation

Many instructors also expressed concern that implementing certain inclusive teaching strategies might result in

pushback or resistance from students. For example, they indicated that students often do not fully participate when instructors try using strategies such as soliciting multiple responses (strategy 7), asking open-ended questions (strategy 10), using think-pair-share (strategy 14), and ensuring participation (strategy 16). In some cases, instructors observed that students feel anxious and panic when asked to respond in front of the whole class. These fears and hesitations lead instructors to use some of the strategies infrequently or not at all. Student resistance is one of the situational barriers that instructors experience to the use of innovative teaching practices [24,25,47]. However, there are many ways to use evidence-based teaching strategies successfully without putting students on the spot or without hurting their feelings [25,48]. Some researchers suggest that classroom participation and discussion should not only be an expectation but also a requirement [47,49]. Thus, the core of this barrier is also related to instructors' lack of knowledge and skills about the strategies. McKee [47] concluded that to encourage student participation, instructors need to create a welcoming classroom environment where students feel safe to express their opinions and share their life experiences.

4. For the lower used inclusive teaching strategies, instructors noted concerns about strategies not being appropriate for a physics classroom and that strategies might make students uncomfortable

Instructors also mentioned other barriers that are mostly found among low used strategies. They said some of the strategies are not relevant to physics classrooms. For example, learning about higher education culture (strategy 17), integrating culturally diverse examples (strategy 19), and understanding students' backgrounds (strategy 21) were described as not relevant. Some instructors think these are not needed in physics classrooms and are more relevant to courses like sociology. Consistent with prior research that found instructors with colorblind mindsets tended to use less inclusive teaching strategies [15]. Many of these strategies that instructors in our study did not use widely require acknowledging student identities. Emerging research also suggests that the use of inclusive teaching strategies may be related to instructor empathy [50–52]. An empathetic instructor communicates effectively outside of the classroom and demonstrates a genuine desire to get to know their students' backgrounds better [44]. Building positive interactions and empathy with students requires that instructors understand students' prior experiences and perspectives [44,53].

Instructors also expressed concern that the activities related to these inclusive teaching strategies might put students on the spot and, thus, not create a comfortable environment in the classroom. For example, some instructors thought that understanding students' backgrounds (strategy 21) would represent an intrusion into students' personal lives which negatively highlights differences between students. Even though

research shows that these concerns are not valid [44,53], these beliefs impede instructors' instructional choices and play a role in the low use of these strategies. Thus, similar to concerns about student resistance, the core of this barrier is related to instructors' lack of knowledge and skills about the strategies.

In summary, our answer to research question 2 is that, while instructors appear to value promoting the sense of belonging of all students, they often lack the knowledge and skill needed to do so effectively. They also often perceived the need to explicitly cover large amounts of course content as in conflict with many inclusive teaching strategies. This belief is not consistent with research results suggesting that most students actually learn more physics when inclusive teaching strategies are used.

IX. SUMMARY AND RECOMMENDATIONS

A. Summary

In this paper, we used interviews with 11 physics instructors who teach introductory calculus-based physics to understand their knowledge about and use of 23 inclusive teaching practices. We make four major claims based on these interviews.

1. *Instructors do not make use of the full range of inclusive teaching strategies.* They systematically use some types of inclusive teaching strategies while avoiding other types. Their description of the use of these strategies suggests that they think they make more use of the strategies than they actually do. Instructors are generally happy with their current use of inclusive teaching strategies and are not particularly interested in using them more.
2. *Instructors value and use inclusive teaching strategies that they think help students learn physics.* Basically, instructors gave only two reasons for using inclusive teaching strategies: helping to learn physics and promoting a sense of belonging. Instructors prioritize inclusive teaching strategies that they think help students learn the physics content. While many instructors also value promoting students' sense of belonging, this value is less important and less prominent than helping students learn physics.
3. *Instructors do not use or do not fully use many strategies due to not fully understanding the strategy.* The biggest barrier that instructors noted is their lack of knowledge and skill about how to use specific strategies. We also noted in our analysis that instructors often had an incomplete understanding of inclusive teaching strategies that resulted in use that is not likely to be optimized.
4. *Instructors do not use strategies that require acknowledging student identities.* Some instructors explicitly noted that they did not use some of the instructional strategies because the strategies were not appropriate for a physics classroom. These

strategies were the ones that required acknowledging the role of identity in physics teaching and learning. Other instructors simply did not use these strategies and did not provide explicit reasons.

B. Recommendations

In order to promote the increased use of a wider range of inclusive teaching strategies, we make the following recommendations.

Build on instructors' existing, but weak, value of promoting students' sense of belonging. The importance of this value can likely be strengthened by helping instructors understand that students who feel a sense of belonging also learn physics content better. Instructors do talk about and value promoting students' sense of belonging, but not as strongly as they value students learning physics content. However, research shows that a sense of belonging is highly correlated with students' learning outcomes [54–56], including physics content [21,57,58]. Helping instructors see this connection could help to strengthen their support for a broader set of inclusive teaching strategies. For example, Hirst *et al.* [59] found that a faculty learning community involving readings and discussions around the sense of belonging was able to increase science instructors' use of inclusive teaching strategies.

Help instructors understand that identity is relevant in physics and feel comfortable talking about it. The male instructors we interviewed tended to reject strategies that explicitly acknowledge the role of identity in the teaching and learning of physics. This is similar to research findings that suggest science faculty believe science is a meritocracy [26,60]. In addition, science faculty who do express interest in promoting equity are often treated with skepticism by their colleagues for introducing “politics” into the domain of pure science [60]. Following recommendations from the Guide to Effective Practices for Physics Programs (EP3), the first step for physics departments to become more equitable is that departments and people within the departments need to educate themselves about equity, diversity, and inclusion [61]. For example, by reading about the culture of physics to understand that physics is not currently a meritocracy [62–65]. Physics instructors can also be encouraged to examine their course outcome data by race, gender, etc [66].

Continue to provide professional development to help instructors develop the necessary knowledge and skills to use the full range of inclusive teaching strategies. Instructors are not using inclusive teaching strategies enough and they are not using them in the recommended ways. They are using some inclusive teaching strategies to a limited extent but without fully understanding many of the details. These instructors have a lack of understanding and a lack of resources that impede more robust implementation. Additional support could help address this barrier. There are many research-based recommendations for how to provide such support through professional development programs [67]. For example, one type of support could be

clear explanations of why and how the strategy works by providing useful resources [10,68]. Another type of support could be mentoring to provide instructors with feedback on their implementation [69,70]. Co-teaching has also been shown to change the beliefs and practices of college science instructors [71,72].

While we have presented some conclusions and recommendations in this paper that we think are sufficiently grounded in our data as well as the results of other studies, we acknowledge that this is a relatively small and preliminary study with a monolithic participant population. Our overarching recommendation is that significantly more research is needed in order to understand how to best promote the widespread use of inclusive teaching in a way that will address the equity challenges faced by physics and other STEM fields.

ACKNOWLEDGMENTS

We would like to thank our 11 instructors who were interviewed in this study. We appreciate that they dedicated their valuable time to research in physics education, aiming to enhance teaching and learning. We would also like to thank three anonymous reviewers for their valuable insights and constructive feedback on the earlier version of this manuscript.

DATA AVAILABILITY

The data that support the findings of this article are not publicly available because they contain sensitive personal information. The data are available from the authors upon reasonable request.

APPENDIX A: INTERVIEW PROTOCOL

1. Introduction

Thank you for taking part in this interview with me. For my research, I am interviewing instructors from different institutions who teach introductory-level calculus-based physics courses. I am interested to investigate your views and experiences about teaching practices. I am also interested to know what situational factors you experience in your classroom that support or disrupt your teaching. I will start with some general questions about your classroom and then we will talk about teaching practices.

2. General questions (Follow-up questions are in italics)

1. How long have you been teaching in general and how often do you teach this course?
2. Please tell me about a typical day in your introductory physics course. For example, what do you do? What do you expect the students to do?
 - a. *What types of students take your class? (How many students, what majors, what genders, what races, what ages, backgrounds, etc.).*
 - b. *Please describe your classroom setting.*

3. How has your instruction changed over time?
 - a. *What led to these changes?*
4. What opportunities have you had to learn about instructional strategies for teaching introductory physics?
 - a. *May be new faculty workshops, conferences, talking to colleagues, and/or teaching and learning center on campus, etc?*
5. Have you heard the term “inclusive teaching” before?
 - a. *What does it mean to you? how did you get to know about this?*
 - b. *What do you do in your introductory physics course that might fall under that category of inclusive teaching?*

3. The main part of the interview
(Follow-up questions are in italics)

1. Recently “Inclusive Teaching” has received a lot of attention in many education circles. Inclusive teaching is a pedagogical approach that supports all students regardless of their identity, level of understanding, and any form of diversity.
 - a. *(If they didn’t answer before...) What do you do in your introductory physics course that might fall under that category of inclusive teaching?*
2. Now I will share my screen for a table that includes a bunch of strategies that promote inclusive teaching. I will be asking you some questions regarding the usage of those strategies.
 Sharing PowerPoint on the screen of the list of inclusive teaching strategies (Table I) and Likert scale (Table III).
3. It is not expected that you use all of those items. Please go down the list and use the Likert scale to tell me if you use each of these practices.

If he/she uses the items (Not every question will be asked for each strategy. Adjust the following questions to fit each strategy. Adjust the words of the questions to fit the sentence of each strategy and to maintain the flow between switching questions):

- a. *How do you do/use that? Does the whole class do that? Or do only some students do that? How frequently you do/use that?*
- b. *Why do you think this is important? Or what might be the benefits of using/doing it more?*

- c. *Do you encounter any difficulties with the higher use of this item?*

If he/she does not use any item (Not every question will be asked for each strategy. Adjust the following questions to fit each strategy. Adjust the words of the questions to fit the sentence of each strategy and to maintain the flow between switching questions):

- d. *Why don’t you use/do this? Or why don’t you use/do it more?*
- e. *Do you think it would be helpful for students if you use/do it more? Or have you ever thought about using/doing it more or do you initiate it sometimes?*
- f. *What are the barriers or concerns about using/doing this item? Or what would be the pros and cons if you use/do it more?*

If he/she chooses below 4 on the Likert Scale (Adjust the following question to fit each strategy. Adjust the words of the question to fit the sentence of each strategy and to maintain the flow of their language):

- g. *Do you want to use/do it more frequently in the future?*

4. Reflection on inclusive teaching
(Follow-up questions are in italics)

1. What is your overall thinking about inclusive teaching now?
 - a. *Were you already familiar with some of these strategies? If yes, how did you get to know about these?*
2. Are you interested in using more of these inclusive teaching practices in your instruction? Why or why not?
 - a. *If yes, do you envision any difficulties using them?*
 - b. *How would you overcome these difficulties?*
3. Do you think that your institution or department would be happy if you used more inclusive teaching practices?
 - a. *To what extent do your colleagues use inclusive teaching practices?*
4. Do you have any other thoughts about inclusive teaching that you think might be relevant, but that I haven’t thought to ask about?

Thank you so much for your time. It was my pleasure to talk to you. I appreciate your kind responses as a contribution to science education research.

APPENDIX B: THE REASON WHY INSTRUCTORS VALUE OR DEVALUE INCLUSIVE TEACHING STRATEGIES?

No	Strategies	Affordance		Barriers			
		Learn physics	Sense of belonging	Students' resistance	Not for physics classroom	Limited time	Lack of knowledge and skills
		Bolded letters are the instructors who reported or indicated these affordances and barriers					
High used	1. Wait time	A, B , C , D , E, F, G, H , I , J , K	A, B, C, D, E , F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K
	2. Interact with students	A, B , C , D , E , F, G, H , I , J , K	A, B, C, D , E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K
	3. Timely feedback	A, B, C, D, E , F, G, H , I , J , K	A, B, C, D , E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B , C, D, E , F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K
	4. Use names	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D , E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K
	5. Praise with caution	A, B , C, D, E, F, G, H , I , J , K	A, B, C, D, E , F, G, H , I , J , K	A, B , C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D , E, F, G, H , I , J , K
	6. Respectful climate	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B , C, D, E, F, G, H , I , J , K
	7. Solicit multiple responses	A, B , C, D, E, F, G, H , I , J , K	A, B, C, D, E , F, G, H , I , J , K	A, B , C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B , C, D, E, F, G, H , I , J , K
	8. Pre- and post-class assessment	A, B, C, D, E , F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B , C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D , E, F, G, H , I , J , K
Medium used	9. Promote collaboration	A, B , C, D , E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K
	10. Open-ended question	A, B , C, D , E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B , C, D , E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B , C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K
	11. Share own difficulties	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K
	12. Learn about racism and sexism	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E , F, G, H , I , J , K	A, B , C, D, E, F, G, H , I , J , K	A, B , C, D , E, F, G, H , I , J , K
	13. Low stake assessments	A, B , C, D, E , F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D , E, F, G, H , I , J , K
	14. Think-pair-share	A, B , C, D , E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B , C, D, E , F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B , C, D, E, F, G, H , I , J , K	A, B , C, D, E, F, G, H , I , J , K
	15. Survey students	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K
	16. Ensure everyone's participation	A, B, C, D , E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B , C, D, E , F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K
Low used	17. Learn about the culture of higher education	A, B, C, D, E, F, G, H , I , J , K	A, B , C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E , F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K
	18. Small group activities	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D , E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D , E, F, G, H , I , J , K
	19. Culturally diverse examples	A, B, C, D, E, F, G, H , I , J , K	A, B , C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D , E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B , C, D , E, F, G, H , I , J , K
	20. Share pronouns	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K
	21. Understand student's background	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D , E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B , C, D, E , F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K
	22. Explain your teaching practices	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K
	23. Share your positionality	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B, C, D, E, F, G, H , I , J , K	A, B , C, D, E, F, G, H , I , J , K

APPENDIX C: INSTRUCTORS' INTENTIONS TO USE INCLUSIVE TEACHING STRATEGIES MORE FULLY

Strategies	Number of instructors who self-reported below 4 on the Likert scale (0 = not at all descriptive of my teaching, 4 = very descriptive of my teaching)	Number of instructors who selected each value below 4 on the Likert scale and want to use the strategy more.				Number of instructors who selected each value below 4 on the Likert scale and do not want to use the strategy more.				Number of instructors who selected each value below 4 on the Likert scale and are not certain about their future use of the strategy.			
		Likert scale				Likert scale				Likert scale			
		0	1	2	3	0	1	2	3	0	1	2	3
1. Wait time	2								1				1
2. Interact with students	3								3				
3. Timely feedback	5				4				1				
4. Use names	4		1	1	1				1				
5. Praise with caution	5			1				1	2				1
6. Respectful climate	4							3			1		
7. Solicit multiple responses	6			1	2			1	2				
8. Pre- and post-class assessment	5						1	2	1				1
9. Promote collaboration	6					1	1		1				3
10. Open-ended question	6			1			1	2					2
11. Share own difficulties	7					1		2	3		1		
12. Learn about racism and sexism	6			2		2			2				
13. Low stake assessments	8		1		1			4	2				
14. Think-pair-share	8		1		1	1	2	1	2				
15. Survey students	9	1		1	2	1	1		3				
16. Ensure everyone's participation	10				3	3	1	1	1			1	
17. Learn about the culture of higher education	9		1	2		3			3				
18. Small group activities	8	1		1		2	1	1	1				1
19. Culturally diverse examples	9	2						3		1	1	1	1
20. Share pronouns	7	2	1			2					1	1	
21. Understand student's background	10		1	1		3	2		1		1		1
22. Explain your teaching practices	10					5			2	1		1	1
23. Share your positionality	9		1			3				4			1

- [1] Y. Ma and Y. Liu, Race and STEM degree attainment, *Sociol. Compass* **9**, 609 (2015).
- [2] National Center for Education Statistics, Number, and percentage distribution of science, technology, engineering, and mathematics (STEM) degrees/certificates conferred by postsecondary institutions, by race/ethnicity, level of degree/certificate, and sex of student: Academic years 2011–12 through 2020–21 (Table 318.45) (U.S. Department of Education, 2022) [accessed November 29, 2024], https://nces.ed.gov/programs/digest/d22/tables/dt22_318.45.asp.
- [3] American Physical Society, Diversity in physics, <https://www.aps.org/learning-center/statistics/diversity> [accessed December 10, 2024].
- [4] X. Chen, STEM attrition: College students' paths into and out of STEM fields, Statistical Analysis Report No. NCES 2014-001, National Center for Education Statistics, 2013.
- [5] E. Seymour, A. B. Hunter, and R. P. Harper, *Talking About Leaving Revisited: Persistence, Relocation, and Loss in Undergraduate STEM Education* (Springer, Cham, 2019).
- [6] V. Sathy and K. A. Hogan, Want to reach all of your students? Here's how to make your teaching more inclusive, in *Chronicle of Higher Education* (The Chronicle of Higher Education, Inc., Washington, DC, 2019), <https://www.chronicle.com/article/how-to-make-your-teaching-more-inclusive/>.
- [7] B. Dewsbury and C. J. Brame, Inclusive teaching, *CBE Life Sci. Educ.* **18**, fe2 (2019).
- [8] J. Amayo, S. Heron, N. Spell, and H. Gooding, Twelve tips for inclusive teaching, *MedEdPublish* **10**, 81 (2021).
- [9] M. Molbaek, Inclusive teaching strategies—dimensions and agendas, *Int. J. Inclusive Educ.* **22**, 1048 (2018).
- [10] T. M. Addy, P. M. Reeves, D. Dube, and K. A. Mitchell, What really matters for instructors implementing equitable and inclusive teaching approaches, *Improve Acad.* **40**, 1 (2021).
- [11] O. Brussino, Building capacity for inclusive teaching: Policies and practices to prepare all teachers for diversity and inclusion, OECD Education Working Papers, No. 256, OECD Publishing, Paris, 2021, <https://doi.org/10.1787/57fe6a38-en>.
- [12] K. D. Tanner, Structure matters: Twenty-one teaching strategies to promote student engagement and cultivate classroom equity, *CBE Life Sci. Educ.* **12**, 322 (2013).
- [13] K. Gannon, The case for inclusive teaching, in *The Chronicle of Higher Education* (The Chronicle of Higher Education, Inc., Washington, DC, 2018), p. 27, <https://www.chronicle.com/article/the-case-for-inclusive-teaching/>.
- [14] K. T. Lindner, L. Nusser, K. Gehrler, and S. Schwab, Differentiation and grouping practices as a response to heterogeneity—teachers' implementation of inclusive teaching approaches in regular, inclusive and special classrooms, *Front. Psychol.* **12**, 676482 (2021).
- [15] O. R. Aragón, J. F. Dovidio, and M. J. Graham, Colorblind and multicultural ideologies are associated with faculty adoption of inclusive teaching practices, *J. Diversity Higher Educ.* **10**, 201 (2017).
- [16] G. M. Walton and G. L. Cohen, A question of belonging: Race, social fit, and achievement, *J. Pers. Soc. Psychol.* **92**, 82 (2007).
- [17] G. M. Walton, G. L. Cohen, D. Cwir, and S. J. Spencer, Mere belonging: the power of social connections, *J. Pers. Soc. Psychol.* **102**, 513 (2012).
- [18] S. Freeman, S. L. Eddy, M. McDonough, M. K. Smith, N. Okoroafor, H. Jordt, and M. P. Wenderoth, Active learning increases student performance in science, engineering, and mathematics, *Proc. Natl. Acad. Sci. U.S.A.* **111**, 8410 (2014).
- [19] E. J. Theobald, M. J. Hill, E. Tran, S. Agrawal, E. N. Arroyo, S. Behling, and S. Freeman, Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math, *Proc. Natl. Acad. Sci. U.S.A.* **117**, 6476 (2020).
- [20] D. C. Haak, J. HilleRisLambers, E. Pitre, and S. Freeman, Increased structure and active learning reduce the achievement gap in introductory biology, *Science* **332**, 1213 (2011).
- [21] S. Getty, N. Gosnell, B. Whitten, and J. Taylor, Supporting inclusive teaching in introductory college physics, *Phys. Teach.* **58**, 312 (2020).
- [22] K. M. Cooper, B. Haney, A. Krieg, and S. E. Brownell, What's in a name? The importance of students perceiving that an instructor knows their names in a high-enrollment biology classroom, *CBE Life Sci. Educ.* **16**, ar8 (2017).
- [23] S. A. Karabenick, Seeking help in large college classes: A person-centered approach, *Contemp. Educ. Psychol.* **28**, 37 (2003).
- [24] C. Henderson and M. H. Dancy, Barriers to the use of research-based instructional strategies: The influence of both individual and situational characteristics, *Phys. Rev. ST Phys. Educ. Res.* **3**, 020102 (2007).
- [25] M. A. Jackson and M. P. Wenderoth, A thematic analysis of interviews reveals how a STEM faculty development program supported the complexity of implementing evidence-based teaching, *Improve Acad.* **43** (2024).
- [26] T. Russo-Tait, Color-blind or racially conscious? How college science faculty make sense of racial/ethnic underrepresentation in STEM, *J. Res. Sci. Teach.* **59**, 1822 (2022).
- [27] V. Braun and V. Clarke, Using thematic analysis in psychology, *Qual. Res. Psychol.* **3**, 77 (2006).
- [28] M. I. Alhojailan, Thematic analysis: A critical review of its process and evaluation, in *WEI International European Academic Conference Proceedings, Zagreb, Croatia* (West East Institute, Zagreb, Croatia, 2012), <https://www.semanticscholar.org/paper/THEMATIC-ANALYSIS%3A-A-CRITICAL-REVIEW-OF-ITS-PROCESS-Ibrahim/0c66700-a0f4b4a0626f87a3692d4f34e599c4d0e>.
- [29] M. Maguire and B. Delahunt, Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars, *All Ireland J. Higher Educ.* **9**, 3352 (2017), <https://ojs.aishe.org/index.php/aishe-j/article/view/335>.
- [30] J. Caulfield, How to do thematic analysis step-by-step guide & examples, Scribbr, <https://www.scribbr.com/methodology/thematic-analysis/> (2023) [accessed November 29, 2024].
- [31] L. Ulriksen, L. M. Madsen, and H. T. Holmegaard, Why do students in stem higher education programmes drop/opt out?—explanations offered from research, in *Understanding student participation and choice in science and technology education* (Springer, Dordrecht, Netherlands, 2014), pp. 203–217.

- [32] W. Cobern and B. Adams, When interviewing: How many is enough?, *Int. J. Assess. Tools Educ.* **7**, 73 (2020).
- [33] A. J. Onwuegbuzie and N. L. Leech, Validity and qualitative research: An oxymoron?, *Qual. Quant.* **41**, 233 (2007).
- [34] J. W. Creswell and V. L. P. Clark, *Designing and Conducting Mixed Methods Research* (Sage Publications, 2017), https://collegepublishing.sagepub.com/products/designing-and-conducting-mixed-methods-research-3-241842?utm_source=chatgpt.com.
- [35] G. Reischauer, Combining artefact analysis, interview and participant observation to study the organizational sense-making of knowledge-based innovation, *Hist. Soc. Res.* **40**, 279 (2015).
- [36] C. Hofisi, M. Hofisi, and S. Mago, Critiquing interviewing as a data collection method, *Mediterr. J. Soc. Sci.* **5**, 60 (2014), <https://www.richtmann.org/journal/index.php/mjss/article/view/3280>.
- [37] C. Helba, A. M. Porter, S. Nicholson, and R. Ivie, *Women among Physics and Astronomy Faculty* (American Institute of Physics, College Park, MD, 2019).
- [38] C. Henderson, M. Dancy, and M. Niewiadomska-Bugaj, Use of research-based instructional strategies in introductory physics: Where do faculty leave the innovation-decision process?, *Phys. Rev. ST Phys. Educ. Res.* **8**, 020104 (2012).
- [39] S. L. Hartman and M. S. Nelson, What we say and what we do: Self-reported teaching behavior versus performances in written simulations among medical school faculty, *Acad. Med.* **67**, 522 (1992).
- [40] S. M. Koziol, Jr. and P. Burns, Teachers' accuracy in self-reporting about instructional practices using a focused self-report inventory, *J. Educ. Res.* **79**, 205 (1986).
- [41] H. M. Ernst, J. Wittwer, and T. Voss, Do they know what they know? Accuracy in teacher candidates' self-assessments and its influencing factors, *Br. Educ. Res. J.* **49**, 649 (2023).
- [42] J. Kaufman and B. Junker, What drives alignment between teachers' survey self-reports and classroom observations of standards-based mathematics instruction?, in *Society for Research on Educational Effectiveness* (Society for Research on Educational Effectiveness, Evanston, IL, 2011), <https://eric.ed.gov/?id=ED528877>.
- [43] C. Henderson and M. H. Dancy, Impact of physics education research on the teaching of introductory quantitative physics in the United States, *Phys. Rev. ST Phys. Educ. Res.* **5**, 020107 (2009).
- [44] B. M. Dewsbury, Deep teaching in a college STEM classroom, *Cult. Stud. Sci. Educ.* **15**, 169 (2020).
- [45] C. Turpen, M. Dancy, and C. Henderson, Perceived affordances and constraints regarding instructors' use of peer instruction: Implications for promoting instructional change, *Phys. Rev. Phys. Educ. Res.* **12**, 010116 (2016).
- [46] C. I. Petersen, P. Baeppler, A. Beitz, P. Ching, K. S. Gorman, C. L. Neudauer, and D. Wingert, The tyranny of content: "Content coverage" as a barrier to evidence-based teaching approaches and ways to overcome it, *CBE Life Sci. Educ.* **19**, ar17 (2020).
- [47] R. J. McKee, Encouraging classroom discussion, *J. Soc. Sci. Educ.* **14**, 66 (2015).
- [48] H. I. Modell, Preparing students to participate in an active learning environment, *Adv. Physiol. Educ.* **270**, S69 (1996).
- [49] E. J. Dallimore, J. H. Hertenstein, and M. B. Platt, Classroom participation and discussion effectiveness: Student-generated strategies, *Commun. Educ.* **53** (2004).
- [50] T. M. Makoele, Teacher empathy: A prerequisite for an inclusive classroom, *Encycl. Teach. Educ.* **11**, 27 (2019).
- [51] C. A. Warren, Empathy, teacher dispositions, and preparation for culturally responsive pedagogy, *J. Teach. Educ.* **69**, 169 (2018).
- [52] C. A. Warren, Towards a pedagogy for the application of empathy in culturally diverse classrooms, *Urban Rev.* **46**, 395 (2014).
- [53] G. McAllister and J. J. Irvine, The role of empathy in teaching culturally diverse students: A qualitative study of teachers' beliefs, *J. Teach. Educ.* **53**, 433 (2002).
- [54] S. Zumbunn, C. McKim, E. Buhs, and L. R. Hawley, Support, belonging, motivation, and engagement in the college classroom: A mixed method study, *Instr. Sci.* **42**, 661 (2014).
- [55] G. M. Walton and G. L. Cohen, A brief social-belonging intervention improves academic and health outcomes of minority students, *Science* **331**, 1447 (2011).
- [56] J. P. McKinney, K. G. McKinney, R. Franiuk, and J. Schweitzer, The college classroom as a community: Impact on student attitudes and learning, *Coll. Teach.* **54**, 281 (2006).
- [57] Y. Li and C. Singh, Sense of belonging is an important predictor of introductory physics students' academic performance, *Phys. Rev. Phys. Educ. Res.* **19**, 020137 (2023).
- [58] S. Cwik and C. Singh, Students' sense of belonging in introductory physics course for bioscience majors predicts their grade, *Phys. Rev. Phys. Educ. Res.* **18**, 010139 (2022).
- [59] R. A. Hirst, K. L. Anderson, B. W. L. Packard, L. J. Liotta, B. H. Bleakley, P. J. Lombardi, and K. C. Burkholder, Faculty learning at the individual and group level: A multi-year analysis of an interdisciplinary science faculty learning community focused on inclusive teaching and mentoring, *J. Coll. Sci. Teach.* **50**, 20 (2021).
- [60] M. Blair-Loy and E. A. Cech, *Misconceiving Merit: Paradoxes of Excellence and Devotion in Academic Science and Engineering* (University of Chicago Press, 2022), https://press.uchicago.edu/ucp/books/book/chicago/M/bo-161019313.html?utm_source=chatgpt.com.
- [61] EP3 Initiative, "Guide to equity, diversity, and inclusion," Version 2021.1, in *A Guide to Effective Practices for Physics Programs (EP3)*, edited by S. B. McKagan, D. A. Craig, M. Jackson, and T. Hodapp (American Physical Society, College Park, MD, 2021).
- [62] M. Dancy and A. K. Hodari, How well-intentioned white male physicists maintain ignorance of inequity and justify inaction, *Int. J. STEM Educ.* **10**, 45 (2023).
- [63] L. M. Santana and C. Singh, Effects of male-dominated physics culture on undergraduate women, *Phys. Rev. Phys. Educ. Res.* **19**, 020134 (2023).
- [64] S. Traweek, *Beamtimes and Lifetimes* (Harvard University Press, 2009), https://www.researchgate.net/publication/302882957_Beamtimes_and_Lifetimes_The_World_of_High_Energy_Physicists.

- [65] L. McCullough, Gender in the physics classroom, *Phys. Teach.* **45**, 316 (2007).
- [66] T. B. McNair, E. M. Bensimon, and L. Malcom-Piqueux, *From Equity Talk to Equity Walk: Expanding Practitioner Knowledge for Racial Justice in Higher Education* (John Wiley & Sons, New York, 2020).
- [67] W. J. Jacob, W. Xiong, H. Ye, S. Wang, and X. Wang, Strategic best practices of flagship university professional development centers, *Prof. Dev. Educ.* **45**, 801 (2019).
- [68] M. E. Bathgate, O. R. Aragón, A. J. Cavanagh, J. Frederick, and M. J. Graham, Supports: A key factor in faculty implementation of evidence-based teaching, *CBE Life Sci. Educ.* **18**, ar22 (2019).
- [69] J. Fountain and K. E. Newcomer, Developing and sustaining effective faculty mentoring programs, *J. Publ. Affairs Educ.* **22**, 483 (2016).
- [70] R. A. Berk, J. Berg, R. Mortimer, B. Walton-Moss, and T. P. Yeo, Measuring the effectiveness of faculty mentoring relationships, *Acad. Med.* **80**, 66 (2005).
- [71] K. Haag, S. B. Pickett, G. Trujillo, and T. C. Andrews, Co-teaching in undergraduate STEM education: A lever for pedagogical change toward evidence-based teaching?, *CBE Life Sci. Educ.* **22**, es1 (2023).
- [72] C. Henderson, A. Beach, and M. Famiano, Promoting instructional change via co-teaching, *Am. J. Phys.* **77**, 274 (2009).