Building a community of educators: A peer-led pedagogical course for Bioengineering graduate students as TAs and research mentors

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Building a community of educators: A peer-led pedagogical course for Bioengineering graduate teaching assistants

Introduction

Graduate Teaching Assistants (GTAs) are fundamental to the function of many academic departments. Whether serving as course aides, graders, or primary instructors, GTAs play a vital role in teaching, supporting students, and *building a community of belonging in the classroom* [1]–[4]. Well-prepared GTAs with strong pedagogical training have the potential to ease the burden on teaching faculty and may even see improvements in their own development as scientists [5], [6]. Indeed, many studies have illustrated the benefits of training programs for increasing GTA understanding of pedagogical techniques and self-efficacy as educators [1], [7]–[9].

GTA preparation varies widely across institutions and may focus more on policy over pedagogy [10], [11]. It follows that graduate students across institutions often report feeling inadequately prepared for their TAships, having limited access to pedagogical training that is discipline specific, and feeling a lack of support to develop teaching skills beyond the minimal requirements [7], [12].

Adequately preparing GTAs in Bioengineering or Biomedical Engineering programs (henceforth referred to collectively as BioE) can be particularly challenging given the wide range of academic subdisciplines, be it a quantitative technical field or a specialized biological subject area. This academic diversity, of course, is by design. Through a healthy heterogeneity of academic backgrounds and lived experiences, we can find novel ideas, opportunities, and applications at the interface of biology, medicine, and engineering. However, this often leaves BioE GTAs having to teach classes without having prior experience with the material, or struggling to support students with varying degrees of comfort in technical or biological course prerequisites. Thus, a general set of pedagogical skills and a community of practice become imperative.

In response to this, with the support of leadership in our department, we spearheaded a graduate student-led initiative to create, implement, and co-instruct a pedagogical course entitled, BioE 296: "*Evidence-Based Approaches in Effective Teaching & Research Mentorship*." This course is a voluntary offering in the BioE course catalog primarily targeted towards graduate students, but open to medical students, postdoctoral scholars, and faculty alike. We took a student-centered approach in creating the class, aligned with constructivist learning theory, by designing the course to be peer-led by a team of experienced BioE GTAs with active learning class sessions. A unique aspect of our course design was inviting BioE department faculty members to join the class as participants. These experienced instructors contributed by sharing their perspectives and experiences in small group discussions but were otherwise not responsible for leading the class or conversation. Topics for course material were determined by conducting a needs assessment for the BioE graduate student population and reviewing the literature to include topics from pedagogical theory to evidence-based strategies, culminating in a final design project for participants to apply course concepts to their own academic application of individualized interest.

Through our design and implementation, we hypothesized that this pedagogical course would (a) help participants build practical, evidence-based strategies for promoting learning in an educational role and (b) increase participant self-efficacy and preparation as educators, in line with Lent's Social Cognitive Career theory. In this paper we thoroughly explore the design considerations behind the course and the learning environment, and show survey data from participants spanning four cohorts across four years, examining participant experiences and self-reported outcomes. We also seek to lower the barrier-to-entry for other academic departments and institutions to create similar peer-led initiatives for building a sense of community amongst GTAs and educators.

Our ultimate goal is to move the needle towards a cultural shift in our field by encouraging and emphasizing the value of lifelong learning in pedagogical skills for effective and equitable teaching. This is now more important than ever given the intrinsic and ever-increasing student diversity in BioE, alongside the broader context of profound global changes including the rise of AI technology, shifting economic powers and global political tensions, prevailing societal inequalities, climate change, significantly changing social norms, and a global pandemic contributing a further layer of chaos and uncertainty [13].

Background

In this section, a brief review of GTA training models and learning frameworks are described from the education literature, including key elements of effective teaching development, used as a foundation for our pedagogical course design.

GTA training program models

Different universities and departments employ a wide range of models for GTA training programs [14], varying in length (from single day orientations, workshops, or seminars to semester- or year-long mentorship programs, coaching programs, or formal coursework), timing (occuring before the TAship begins or concurrently with the TAship), and depth (from policies and procedures to course-specific content and pedagogical theory) . The most common content covered in department-level trainings include policies, classroom management, and course-specific content [15], while university-level trainings that are not discipline-specific are even more likely to focus on school policies and procedures rather than pedagogy [16]. Though orientations are one of the most common methods used to begin TA preparation [17], they are by themselves often insufficient for adequate training [18]. Unsurprisingly, TAs reported being unprepared for teaching when they only experience brief orientations that are seen as too general to impact teaching [18].

Pedagogy Courses and Workshops

As a more in-depth and comprehensive training workshop series, Roden, Jakob, Roehrig, and Brenner (2018) describe an intensive two-day training workshop for first-year GTAs in the life sciences including four to six 75–90 minute sessions [19]. They describe the sessions as combining instruction in current research and theory supporting teaching science through active learning, teaching practice, and receiving feedback from peers and mentors. Session topics included active learning, evaluating student learning, inclusive teaching, theories of learning, connected communication, practical tips for teaching, and a panel discussion with experienced graduate students. Postworkshop assessments indicated that GTA participants' knowledge of key topics increased during the workshop and in follow-up evaluations, and that the workshop helped them prepare for teaching.

As a discipline-specific pedagogy course, Zehnder (2016) describes a mandatory semester-long course for biology masters students, meeting once a week for 2 hours, with an emphasis on participants working collaboratively, actively learning, and giving and receiving feedback during sessions [20]. Topics covered include active learning, types of assessments, classroom management, informing teaching practice through student course evaluations, teaching a diverse student audience, engaging lecturing, professional behavior, student motivation, teaching strategies, and writing effective exam questions. Student self-assessment of their learning gains post-course indicated moderate to high gains in each topic. Post-course surveys indicated that students valued the in-class peer interactions, peer feedback and the interactions possible within a structured program, in that GTA courses can help build community within a graduate program.

Professional Development Programs

Miller, King, and Martin (2018) present a year-long professional development program for GTAs with monthly face-to-face meetings. Participants were expected to come to each session having watched pre-recorded lectures with readings - however, in post-course surveys only 55% of participants indicated that they completed all of the required readings and activities after the sessions and 73% indicated that they would prefer additional meetings to explore topics in more detail in a guided way rather than having a heavier workload of "homework" for each session [21]. During meetings, participants would be expected to complete active learning activities, exploring content and practicing teaching methods at the same time. A variety of teaching strategies were used to provide formative feedback to students with the goal of creating an open environment of learning and dialogue. Individual assessments and a capstone project were designed to assist participants in both creating artifacts for their own courses, with the final project requiring students to submit a teaching philosophy and submit a professional development plan. Post-course surveys also indicated that participants found technology tool training and exposure to the idea of the scholarship of teaching and learning as useful aspects of the program.

Peer-Led Coaching Programs:

Focusing on mentorship and guidance from experienced graduate student peers, Fantone et al. (2023) describe their design and implementation of a low-time commitment instructional coaching program for chemistry graduate teaching assistants, consisting of 4 hours of total meeting time across a semester [22]. In a "coaching cycle", typically a first-year GTA coachee and a second- to fourth-year GTA coach are paired by the leadership team to enter a three-stage cycle, consisting of a "planning" or a pre-instruction stage, an "implementation" stage with observations and data collection, and a "reflecting" or a post-instruction stage. The main goal was to provide specified, contextualized support (e.g., to the GTA's problem of practice) and sustained support (e.g., with an experienced GTA). Coaching training was implemented in six 1.5 hour, in-person sessions with 3 hours of expected homework time, covering topics such as coaching stances, conversation maps, planning and reflecting meetings, SMART goal setting, building trust, and data collection and sharing. In short-response surveys, coaching recipients reported positive experiences within the coaching program on having developed more teaching skills, having had access to a knowledgeable and skilled GTA, and experiencing positive social and communal interactions with their coach and students.

Elements of effective teaching

Fong, Gilmore, Pinder-Grover, and Hatcher (2017) summarized four key elements of effective teaching development: microteaching, mentoring, feedback on teaching, and reflection on practice [23].

Microteaching

Microteaching involves a simulated teaching experience in that the class size is typically smaller; generally, the audience is one's peers; instruction is abbreviated; and it includes intensive planning, support, and feedback. Metcalf, Ronen Hammer, and Kahlich (1996) found that microteaching relates to increases in teachers' ability to reflect on instruction and implement desirable instructional methods that foster active learning [24].

Mentoring

For engineering programs, Pinder-Grover and Haynes (2015) found that employing teaching mentors was instrumental to guide and support novice TAs [25]. Graduate students can serve as particularly effective TA mentors, having developed effective teaching practices but still carrying fresh memories of novice instructor struggles, making them less likely to suffer from the 'expert blind spot' [26].

Feedback on Teaching

It has been well established that student-provided feedback can enhance college instruction [27]. More recently, Zhu et al. (2013) found that engineering TAs reported that one of the most effective methods for improving their teaching was student feedback [28]. For best practices in collecting feedback, Cox et al. (2011) developed a feedback tool for engineering TAs called the Global Real-Time Assessment Teaching Tool for Teaching Enhancement, utilizing both summative and formative assessments from observers, administrators, GTAs, and undergraduate students [29]. Gilmore, Maher, Feldon, and Timmerman (2014) show that observation and feedback from faculty mentors were predictive of STEM graduate students' development of student-centered, active learning teaching approaches [30].

Reflection on practice

As explained by Osterman and Kottkamp (2004), reflection can be seen as a vehicle for learning to teach and improving one's teaching by identifying instructional problems, gathering data/feedback from students about teaching and learning, and examining data and personal observations to make instructional improvements [31]. DeFranco and McGivney-Burelle (2001) describe reflection as part of a "cyclical learning process" that includes learning new instructional strategies through class activities and discussion, implementing those practices within one's teaching (or microteaching simulations), and reflecting on effectiveness following implementation [32]. TAs can then subsequently share these reflections with each other and foster a greater sense of community among TAs through dialogue about their experiences. Walkington, Christensten, and Kock (2001) describe the importance of "critical reflection" for teachers and students alike, requiring a conscious awareness of understanding a thinking process and utilizing it within practice [33].

Theoretical Framework

Given that the purpose of our work was to a) design and implement a peer-led pedagogy course for BioE GTAs and b) evaluate its impact on participants' self-efficacy as educators, our theoretical framework was informed by constructivist learning theory [34-38] and Lent's Social Cognitive Career Theory [39-40].

Constructivist learning theory

Constructivist learning theory is based on the premise that cognition, or learning, is the result of "mental construction." In other words, students learn by fitting new information together with what they already know. A central tenet of constructivism is that learning is an active process. In constructivist learning environments, the teacher has a role to create a collaborative environment where students are actively involved in their own learning. In this way, teachers are more facilitators of learning than "sages on a stage" simply transmitting knowledge to students. Thus, in a student-centered, constructivist approach to the design of the course, having experienced GTAs act as co-instructors of the course with BioE faculty members engaged in a learning/participant role ensured that knowledge would be shared between teachers and students in a community-oriented environment, allowing course participants to take ownership of their own learning and development.

Lent's Social Cognitive Career Theory (SCCT)

SCCT describes how self-efficacy affects one's performance and vocational pursuits. SCCT purports that self-efficacy is the set of beliefs about one's capability to perform particular behaviors related to career goals. An individual's self-efficacy predicts his or her outcome expectancies, goals, and performance. As Lent et al. (2015) studied for engineering majors, self-efficacy also served as the precursor to interest, satisfaction, and persistence in a career choice within the context of environmental supports and resources [41]. In order to compare the effectiveness of multiple teaching development programs for engineering TAs, Fong et al. (2017) measured participant self-efficacy in teaching with the aim of designing programs that bolster TAs' confidence in teaching effectiveness [23]. Thus, one of the primary outcome measures in evaluating the impact of our pedagogical course on participants was their self-confidence and self-efficacy as educators.

Course Design

Course Learning Goals

We designed a course to address a critical need in the training of graduate TAs by focusing on building pedagogical skills. We employed student-centered course design to create course learning goals that were meaningful and attainable through a weekly seminar course [42]. Specifically, through this course, graduate TAs would be able to: **(1)** build practical skills for defining and accomplishing course or communication objectives; **(2)** implement actionable inclusive strategies to foster belonging and equity within their community; and **(3)** develop a tangible plan for applying effective teaching and communication skills to achieve personal and professional goals. The selection of module topics (**Table 1**) and the structure of each course module (**Table 2**) was rooted in the course learning goals and elements of effective teaching described in literature.

Course Topics

We selected course topics that included the ***why*** (*i.e.*, theoretical knowledge) and the ***how*** (*i.e.*, actionable strategies and skills) of equitable pedagogy after a review of the educational literature and surveying BioE graduate students with TA experience for what topics to prioritize. Our course offers an introduction to critical pedagogy, constructivist learning theory, culturally responsive pedagogy framework, and universal design for learning. The course also covers and uses practical pedagogical techniques for guiding student learning such as active learning strategies, individualized formative feedback models, equitable assessment and rubric design, community values and norms setting, and building a culture of trust and wellness. **Table 1** shows the full syllabus of topics and learning objectives for each week's module.

Final Project

Drawing from constructivist theory and authentic assessment, a final project was designed for participants to tie their conceptual understanding to practice [1]. Each participant chose a personally meaningful pedagogical project and designed a plan for effectively and equitably carrying out their role utilizing skills learned in the course. The learning goals of the project were for participants to: **(1)** Internalize the value of equity-centered teaching practices for improving communication efficacy; **(2)** Identify an area of life or specific role in which effective communication (or, more specifically, effective teaching) will help them achieve their personal or professional goals; **(3)** Describe their vision of effective and equitable communication or teaching in that area of life or role (their pedagogical philosophy); and **(4)** Design a pedagogical artifact that uses course concepts to realize their vision. A detailed description of the final project can be found in **Appendix A1**.

Table 1. Overview of the weekly module topics and associated learning objectives.

Week	Topic	Learning Objectives
1	**Module 1:**	● **Reflect** on what makes a learning experience exciting, engaging, and empowering.

	Effective & Engaging Teaching Part 1: Excitement in Education	● **Explore** the ways in which exciting instruction is an inclusive teaching practice. ● **Identify** concrete strategies to promote inclusion and equity through active learning techniques.
2	**Module 1: Effective & Engaging Teaching** Part 2: Active Learning Strategy Practice	● **Identify** active learning strategies and examine the opportunities and challenges of their implementation in different learning contexts. ● **Design** engaging activities to achieve specific learning goals that are tailored and relevant to a variety of classroom contexts.
3	**Module 2: Design for Learning** Part 1: Structuring Pedagogy with Learning Goals	● **Understand** the utility of backward course design for shaping pedagogy. ● **Apply** Bloom's Taxonomy and the CLEAR SMARTER frameworks to write descriptive learning goals for different learning situations.
4	**Module 2: Design for Learning** Part 2: The Dynamics of Learning	● **Examine** the relationship between learning goals, assessments, and rubrics. ● **Describe** the benefits of rubrics as an equitable teaching and learning tool. ● **Articulate** the role of grades and rewards in motivation of students' learning and **discuss** alternatives.
5	**Module 1 & 2 Review:** Midterm Feedback and Muddiest Points	● **Reflect** on learning objectives from Modules 1 and 2. ● **Identify** muddiest points for developing clarity.
6	**Module 3: Knowing Your Audience** Building a Culture of Trust and Wellness in the Classroom	● **Describe** the Culturally Responsive Teaching (CRT) framework and build vocabulary to discuss cultural biases in the classroom. ● **Identify** one's own implicit biases using the Common Beliefs survey and discuss how these biases may affect how you interact with students in the classroom. ● **Discuss** strategies to promote wellness for both students and teaching teams.
7	**Module 4: Learner-Centered and Situational Feedback** Part 1: Feedback as Dialogue	● **Describe** the mentor's dilemma and how the language of feedback affects student growth. ● **Practice** learner-centered, conversation-based feedback using the Pendleton model. ● **Apply** the SBII model for situational feedback in

		mentorship and/or classroom contexts.
8	**Module 4: Learner-Centered and Situational Feedback** Part 2: Individualized Feedback	● **Identify** multiple social styles and preferred styles of giving and receiving feedback. ● **Practice** conversation-based feedback using a social-style informed approach.
9	**Project Showcase & Course Summary**	● **Implement** communication skills developed throughout the quarter in a Lightning Talk format. ● **Practice** providing feedback and asking insightful questions about an academic talk. ● **Build** a community of educators via discussion of teaching, mentoring, and communication-related interests. ● **Reflect** on your learning experience this quarter and **recommend** next steps for the future of this course.

Table 2. An outline of the daily course structure, including a description of each module phase.

No.	Phase	Description
1	**Welcome Check-In** (5 min)	Each session included a **check-in question** as participants joined. Participants were invited to discuss with others at their table or quietly reflect. This helped build classroom community.
2	**Agenda** (5 min)	When we were ready, we began with the **agenda** for the day and introduced that day's **learning objectives**.
3	**Recall** (5 min)	We then **recalled** the topics covered the week prior. Here, we paused to address lingering questions or new comments. We would also **address feedback** submitted via Exit Ticket during this time.
4	**Reflect** (10 min)	We transitioned to a **reflection** that used the participants' own experiences to link the topic covered the week before to the topic for that day, followed by a **group discussion**. This helped to link past and future knowledge and promoted participation.
5	**Content Knowledge** (15 min)	Once we set the stage, we moved to **knowledge building**. We clarified key concepts or terms, described their use, and introduced data from the literature to motivate its utility. We used reflections or short practice exercises to break up content-heavy sections.
6	**Activity** (25 min)	After providing the necessary information, we would engage the students in a **longer activity** that would allow them to synthesize and deepen their

		understanding of the topic. Examples include a modified **jigsaw activity** for a guided exploration of resources; **small group work** on a practice exercise followed by a **gallery walk**; and a **think-pair-share**. Activities often concluded with a **group discussion**, though we encouraged varied participation methods. This sharing was essential for helping students identify actionable strategies to implement in their teaching practice.
7	**Final Project Work Time** (10 min)	To help participants review and apply concepts covered during the course session, we set aside time at the end of class for students to **work on their projects**, either individually or in small groups. This was a flexible time period that students could also use to **reflect** on the material or **connect** with their peers.
8	**Summary** (5 min)	When wrapping up the class session, we would **revisit the learning objectives** for the day, with additional **visual cues** for each concept.
9	**Exit Ticket** (5 min)	We'd then share a QR code that directed the students to a **feedback form** for that class session.

Methods

Background on Graduate Student Teaching and Training

Graduate students in the BioEngineering Ph.D. program at Stanford University are required to serve as a GTA twice during their degree program, usually once during the second year and once during the third year of graduate school. Graduate students may work as a GTA for a variety of different course structures, ranging from a large introductory undergraduate course to a smaller advanced undergraduate or graduate level course. Our 1-credit pedagogical course was first listed in the University directory under the BioE department with the title, "Promoting Effective and Equitable Teaching in Bioengineering," and was offered online over Zoom in 2021 (no data collection). Since then, the course has been offered in-person during the 10 week Spring quarter from 2022 to 2025. While a university-level and department-level orientation are required for all BioE GTAs, this course is voluntary. To incentivize student participation, with support from departmental leadership, the course counts towards required BioE Ph.D. or M.S. coursework credits. Cohorts have included Ph.D. and M.S. students from the BioE, Mechanical Engineering, Electrical Engineering, and Computer Science departments, alongside medical students and postdoctoral scholars. Graduate student participants ranged from their 1st year to 4th year of study, though the majority of students took the course before their first assigned TAship. Others took the course concurrently or after their first GTA experience. In total, 51 students have participated in the course, with 50 completing all course requirements including submission of a final project.

Course Leadership and Teaching Team

The course was first conceptualized, created, and co-taught by three experienced BioE GTAs from 2021-2022 who were serving as TA coordinators for the department and BioE faculty members serving in an advisory role. BioE faculty members also attended classroom sessions as a learning participant for activities and discussion. Different faculty members have served as a course advisor and classroom participants from year to year. From 2023 - 2025, five new and experienced GTAs who had previously taken the course joined the teaching team to perpetuate the course as previous graduate student instructors graduated. Course development and implementation was supported from 2021-2025 in part with an inclusive teaching fellowship through the Stanford University Center for Teaching and Learning.

Modifications from 2022 through 2025

Based upon yearly student feedback, more discipline-specific BioE examples have been used to frame how active learning strategies can be applied as a GTA in science and engineering courses of various sizes and levels. In 2023, an activity on generating and evaluating rubrics utilizing large language models was also included in the context of the explosive rise of ChatGPT and AI and amidst dialogue surrounding their use in academia. For the 2025 iteration, the course title was updated to "Evidence-Based Approaches in Effective Teaching & Research Mentorship" to emphasize the transferable nature of teaching skills into research mentorship and to frame equitable and inclusive teaching as evidence-based teaching practices. Students were given an expanded set of choices on case studies to discuss as in-class learning activities based upon their various academic and professional interests. These included applying active learning strategies as a TA in a large, computational undergraduate BioE course, as a TA in a graduate-level BioE journal club course, as a project team manager for a Capstone design course, or as a research mentor for an undergraduate student. Updated lecture slides, materials, and assignments are available from the authors by request.

Survey Data Collection and Statistics

Data were collected and analyzed according to a protocol approved for exemption by the Stanford University Institutional Review Board Panel on Medical Human Subjects (IRB #74321).

Participant survey data was collected through pre- and post-course surveys. These surveys measured the participants' self-efficacy, knowledge, and attitudes as inclusive instructors, and were designed in alignment with Lent's Social Cognitive Career Theory, and informed by the institution's Center of Teaching and Learning. Most responses were measured on a Likert scale ranging from 1 to 3 (Low to High, respectively) or 1 to 5 ("Not Well at All" to "Extremely Well," respectively). Pre-course survey responses were acquired from 40/51 course participants. Each of the post-course survey questions had responses from up to 31 of the 51 course participants. Statistical analysis of Likert-scale survey data was performed with nonparametric tests. The post-course survey provided paired, retrospective pre-/post-course assessments of self-efficacy; differences were inferred with the Wilcoxon signed-rank test. For the unpaired samples across both the pre- and post-course assessments, comparisons were made using the Mann-Whitney U test.

Results

Participants accomplished all course learning goals

Participants primarily consisted of inexperienced graduate students with limited prior experience as an instructor or a TA. When asked to indicate their level of previous teaching experience, 24 out of 31 respondents scored their experience level as moderate or below, and of those, 15 indicated having little or no experience. Across all course iterations, 4 respondents were concurrently TAs for another course, while 28 respondents were expecting to serve as a TA or instructor in the future (**Figure 1**).

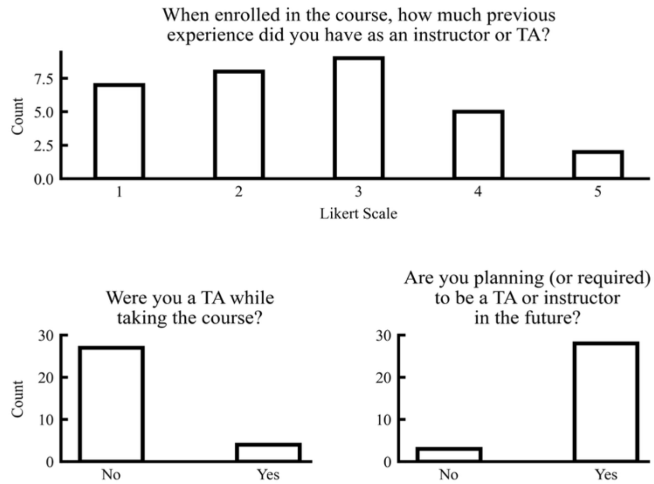

Figure 1. Participant responses (n=31) regarding prior TA experience (top, 1: "no experience", 5: "extensive experience"), concurrent teaching responsibilities (bottom left), and future TA experiences (bottom right).

Participants strongly agreed that the course allowed them to achieve all three course learning goals to **(1)** build practical skills for defining and accomplishing course or communication objectives; **(2)** implement actionable inclusive strategies to foster belonging and equity within the (classroom) community; and **(3)** develop a tangible plan for applying effective teaching and communication skills to achieve personal and professional goals. As shown in **Figure 2**, mean ratings of above 4.5 on a 5-point Likert scale were measured for goals one (Mean ± SD: 4.57 ± 0.57, n=30) two (4.59 ± 0.57, n=29) and three (4.63 ± 0.56, n=30).

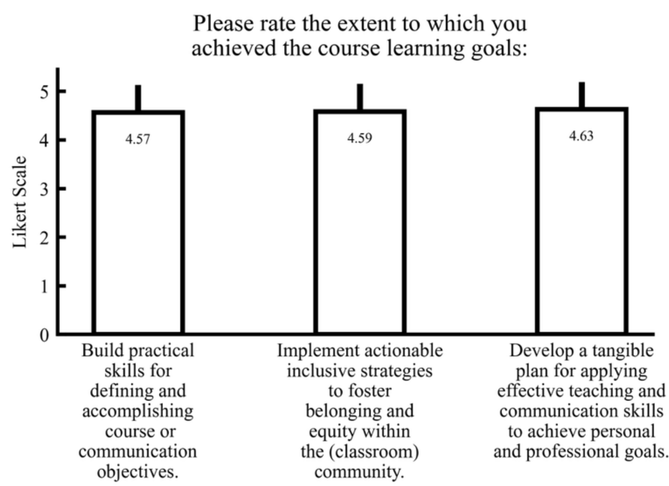

Figure 2. Participant responses (Goal 1: n=30; Goal 2: n=29; Goal 3: n=30) when asked to rate how well they achieved the three course learning goals through participation in the course (1: Not well at all; 5: Extremely well).

To further evaluate the first learning goal of the course, we measured retrospective changes in self-efficacy across core course concepts (**Figure 3**) on a 3-point Likert scale. Pooled across all responses, participants showed a significant increase in self-efficacy ratings (Mean difference ± SD: 0.97 ± 0.70, T=248, $p<0.001$, n=468). In addition, respondents reported increased self-efficacy across each individual course topic (**Figure 3**). Post-course data also showed high scores for measures of course design efficacy (**Figure 4)**, including student engagement (4.63 ± 0.56, n=30) and modeling of inclusive teaching practices (4.77 ± 0.50, n=30).

Please rate your confidence in applying the following techniques or concepts:

Concept	Pre (retrospective)	Post	Stat		
	Mean (SD)	Mean (SD)	T	p	n
Engaging teaching as inclusive teaching	1.48 (0.72)	2.71 (0.46)	0.00	0.000000	31
Active learning techniques	2.00 (0.73)	2.84 (0.37)	0.00	0.000001	31
Culturally responsive teaching	1.58 (0.76)	2.58 (0.50)	0.00	0.000000	31
Identifying & overriding implicit bias	1.77 (0.80)	2.52 (0.57)	0.00	0.000002	31
Creating learning objectives/goals	2.03 (0.80)	2.87 (0.34)	0.00	0.000002	31
Domains of learning & Bloom's taxonomy	1.61 (0.80)	2.71 (0.46)	6.50	0.000002	31
SMARTER & CLEAR goals	1.64 (0.81)	2.73 (0.47)	0.00	0.003906	11
Student-centered course design	1.55 (0.69)	2.55 (0.52)	0.00	0.003906	11
Assessments from learning goals	1.71 (0.74)	2.58 (0.50)	0.00	0.000001	31
Alternative grading and motivation	1.50 (0.53)	2.50 (0.53)	0.00	0.031250	8
Rubrics to communicate expectations	1.74 (0.73)	2.61 (0.50)	9.00	0.000008	31
Holistic and analytic rubrics	1.43 (0.66)	2.57 (0.51)	0.00	0.000004	23
Universal design for learning	1.45 (0.69)	2.82 (0.40)	0.00	0.003906	11
Summative vs formative feedback	1.77 (0.68)	2.77 (0.43)	0.00	0.000000	30
Divergent vs convergent feedback	1.57 (0.66)	2.74 (0.45)	0.00	0.000002	23
Growth mindset	2.09 (0.54)	2.82 (0.40)	0.00	0.007812	11
Individualized feedback	1.73 (0.74)	2.60 (0.50)	0.00	0.000000	30
Pendleton feedback model	1.29 (0.53)	2.39 (0.50)	0.00	0.000000	31
Wellbeing and domains of flourishing	1.52 (0.72)	2.35 (0.61)	0.00	0.000001	31

Figure 3. Average participant feedback listing the self-reported confidence in applying each course topic before and after completing the corresponding course module. Responses were measured on a 3-point Likert scale (1: Low; 2: Moderate; 3: High). Wilcoxon signed-rank test statistics (T), p-values, and sample sizes for each individual concept are shown in the "Stat" section. Variation in sample size is partially due to changes in course content from year to year.

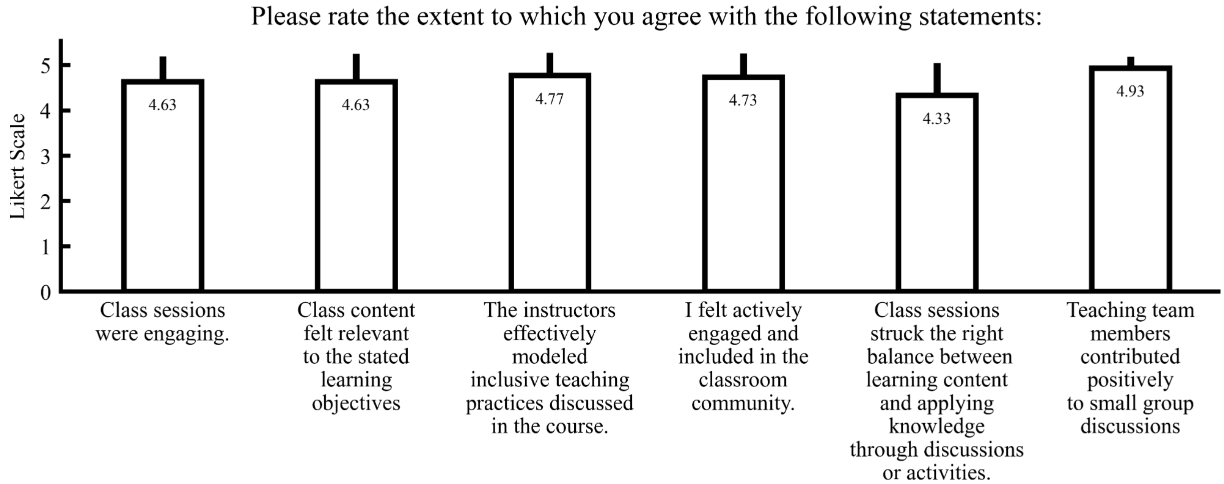

Figure 4. The extent of participant agreement with statements regarding measures of overall course efficacy, including content relevance, student engagement, and community inclusivity. For each question, a sample of n=30 was collected on a 5-point Likert scale (1: Strongly disagree; 5: Strongly agree).

For the second learning goal, participants strongly believed that this course prepared them to promote diversity, equity, and inclusion in the future (4.68 ± 0.54, n=31; **Figure 5**) while being a better overall instructor (4.52 ± 0.68, n=31) and mentor (4.58 ± 0.62, n=31). For the third learning goal, all participants reported that the final project enabled them to successfully describe a vision for their future teaching or communication practices using course concepts (4.87 ± 0.35, n=30) and develop a tangible plan to achieve that vision (4.90 ± 0.31, n=30; **Figure 6**).

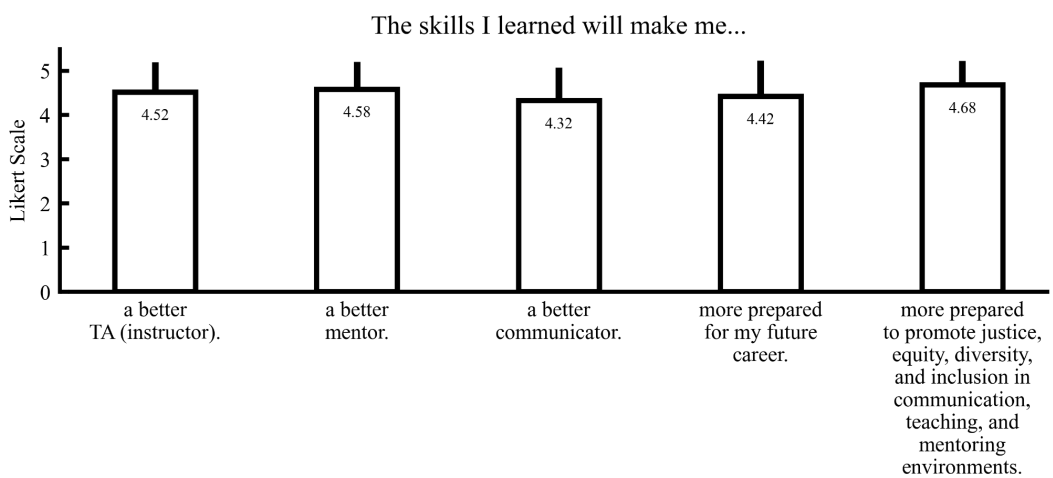

Figure 5. The extent of participant agreement with each statement regarding the utility of skills learned through this course. For each question, a sample of n=31 was collected on a 5-point Likert scale (1: Strongly disagree; 5: Strongly agree).

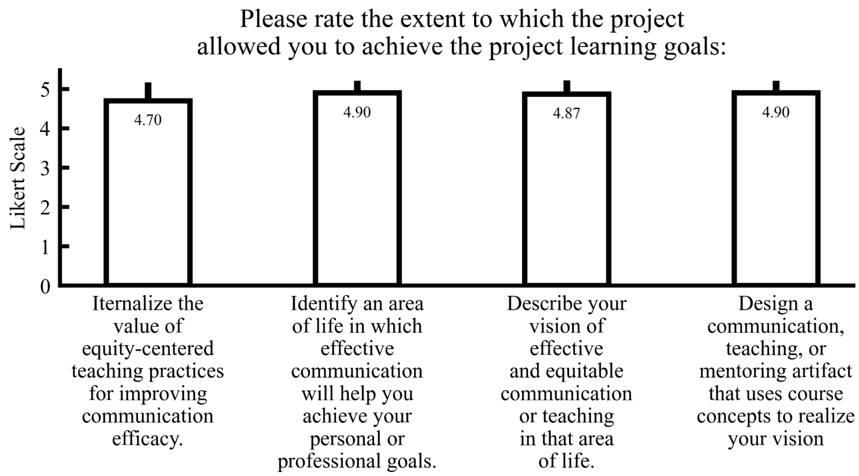

Figure 6. Average self-reported participant scores on achievement of final project learning goals. This demonstrates strong agreement with achieving the third course learning goal. For each question, a sample of n=30 was collected on a 5-point Likert scale (1: Not well at all; 5: Extremely well).

Participants explored a diverse array of topics utilizing the authentic final assessment

Students (n=50) used the open-ended final project to apply course concepts across both teaching (n=27) and research mentorship (n=23) contexts. Examples of past student project topics include teaching philosophy statements, course syllabi, research mentorship plans, and educational resources. A complete list of all final project titles can be found in **Appendix A2**. For these projects, course participants referenced a variety of course concepts, with the five most commonly used topics being learning goals (n=35), universal design for learning (n=24), feedback frameworks (n=23), active learning (n =21), and culturally responsive teaching (n=16) (Figure 7).

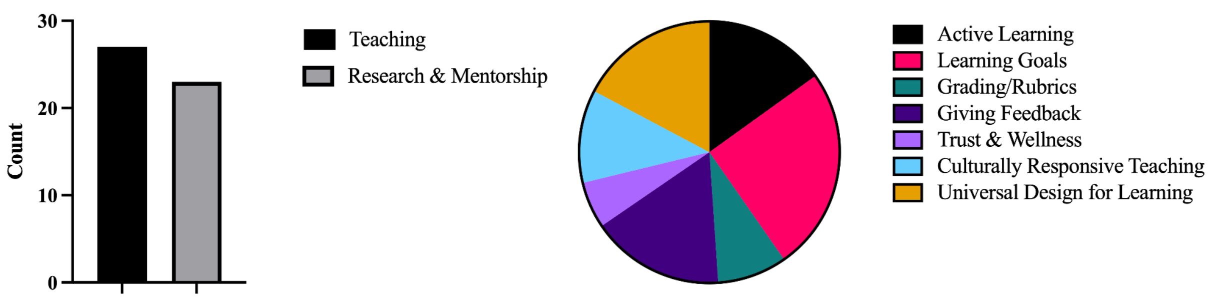

Figure 7. Categories of course participant final project topics and course concepts referenced in the final project deliverable.

Participants showed improvement in their self-efficacy as instructors

We noted a significant increase in participant comfort level with being a TA or mentor after comparing retrospective pre- and post-course self-efficacy evaluations (Pre: 2.68 ± 0.98; Post: 4.26 ± 0.68; $T=0$, $p < 0.001$, $n=31$) as shown in **Figure 8.**

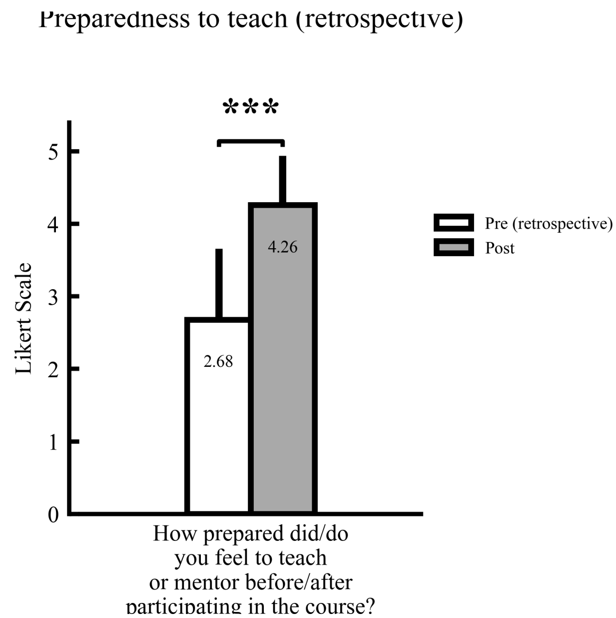

Figure 8. Self-reported participant preparedness to teach or mentor before (white) and after (gray) completing this course (n=31). Preparedness significantly increased in retrospective evaluation (***: p<0.001) of Likert scale rating (1: Not at all prepared; 5: Very prepared).

When asked to explain any change that occurred in participant self-efficacy as a TA or mentor, participants often cited the exposure to helpful tools and practical skills. One participant wrote,

> *"I feel like the strategies that we covered in [the course] will be useful for communicating with students and helping them understand course material."*

This response shows the benefit of covering practical strategies in the course and a link between teaching self-efficacy and the ability to positively impact others' learning. On the topic of actionable strategies, other participants wrote,

> *"The resources and concrete examples to improve course organization and teaching has made me more confident on TAing a class in the future. For example, identifying learning goals or comparing different rubric styles made me realize that there are so many strategies to make learning/teaching effective."*

> *"This class has formalized some of the topics I was previously thinking about (topics include providing effective feedback, goal-setting, and un-grading strategies). This formalization has allowed me to adopt new strategies when mentoring/teaching and given me more tools for planning in the future."*

Another participant left constructive feedback commenting on the timing of the pedagogical course with respect to their future TAship, writing that, *"I understand various strategies to create a more equitable, effective, and inclusive curriculum. I also am able to conduct pedagogical literature reviews. I will be more prepared when I actually gain some experience being a TA for a class here."*

This response reveals the benefit of exposing GTAs to pedagogical theory and strategy while also highlighting a core limitation of timing the pedagogical course to occur before, and not during, a participants' TAship. Other responses cited exposure to theory and pedagogical frameworks as being a major contributor to their increase in preparedness. As one participant explained,

"I feel that before, my preparedness was based on my own previous experience (i.e. what I had personally reflected on). This course equipped me with new resources, perspective, and tools, that I don't think I would have sought on my own, but I believe will improve my teaching."

Exposure to both the tools and the theory was a common theme in responses, as another participant wrote that,

*"I feel more prepared to be a *better* and more holistic TA after the course through the myriad of tools and frameworks we learned."*

Even participants coming in with higher levels of experience as a TA reported increased feelings of preparedness, even if the delta may have been lower in magnitude. A participant wrote,

"I felt very prepared to TA coming into the class because I've been a TA for many semesters in the past, but this class gave me even more tools to work with."

Responses also reflected that taking this course increased participants' motivation to improve their efficacy as teachers, as one participant wrote,

"I feel like I got a better sense of how much TAs can impact their students and am motivated to do a better job because of that."

Filling an unmet need in the GTA training

To answer the questions on whether this pedagogical course filled a gap in GTA training, participants were asked whether they felt the BioE department needed a course on pedagogy and communication skills. Respondents strongly agreed such a course was necessary (4.57 ± 0.82, n=30; **Figure 9**), validating the existence of a crucial gap in graduate TA training. Furthermore, when compared to other technical courses that are required by the department (Research colloquium, Research ethics, unrestricted electives), our course had the highest average ranking (3.56 ± 0.58, n=27) on a scale of 1 to 4 (1: Least important; 4: Most important; **Figure 10**).

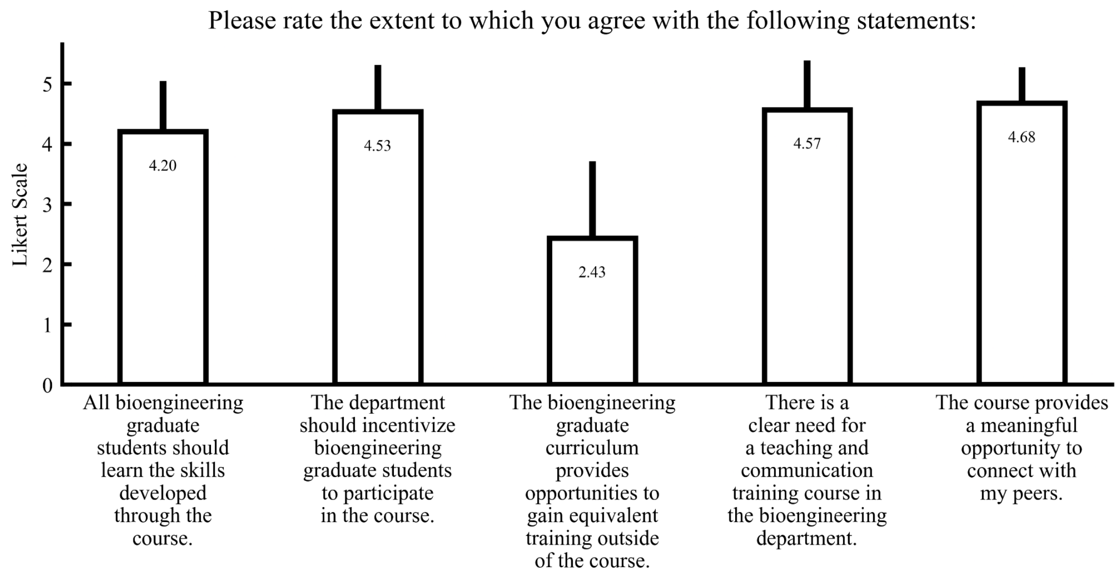

Figure 9. Average participant responses with each statement regarding existing access to pedagogical training and the importance of this course within the department. Responses (n=30 or n=31) were measured on a 5-point Likert scale (1: Strongly disagree; 5: Strongly agree).

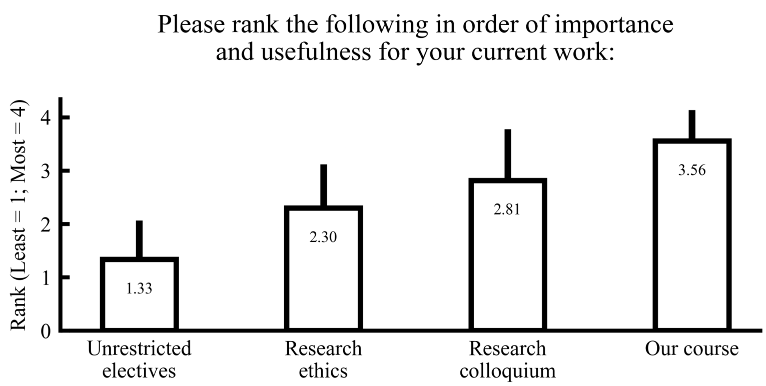

Figure 10. Average participant response (n=27) when asked to rank our course alongside the required department courses and unrestricted electives. A higher rating means the course is perceived as more important (1: Least important; 4: Most important).

Participants reported preparedness and interest in creating inclusive classrooms and building community.

Participants widely acknowledged the course's success in fostering leadership in inclusive teaching and creating a meaningful community. The majority strongly agreed that the course facilitated significant peer connections (4.68 ± 0.60, n=31; **Figure 9**) and actively engaged them in an inclusive classroom environment (4.73 ± 0.52, n=30; **Figure 4**). Contributing to this was a strong preference for the constructivist class structure, where 28/30 respondents preferred having peer instructors with faculty participants; no respondents preferred a course fully run by faculty (**Figure 11**). Respondents also increased in their preparedness to create inclusive classroom environments from a pre- to a post-course evaluation (Pre: 3.80 ± 0.94, n=40; Post: 4.39 ± 0.62, n=31; **Figure 12**), a difference which was statistically significant (U=399.0, p=0.007). Participants also maintained an interest in further exploring inclusive teaching (Pre: 4.93 ± 0.27, n=40; Post: 4.74 ± 0.51, n=31; **Figure 11**).

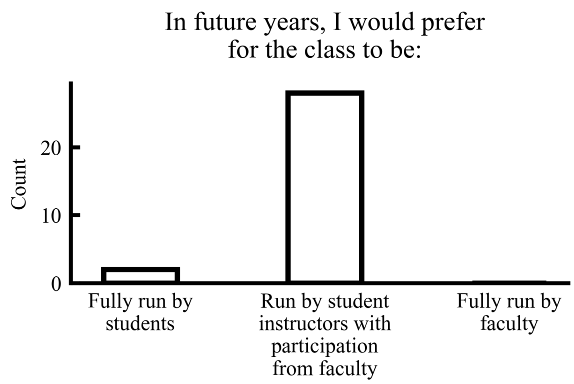

Figure 11. Participant feedback (n=30) on classroom structure utilizing graduate student instructors and faculty participation. Most respondents (28/30) preferred the course to be run by student instructors with faculty participants.

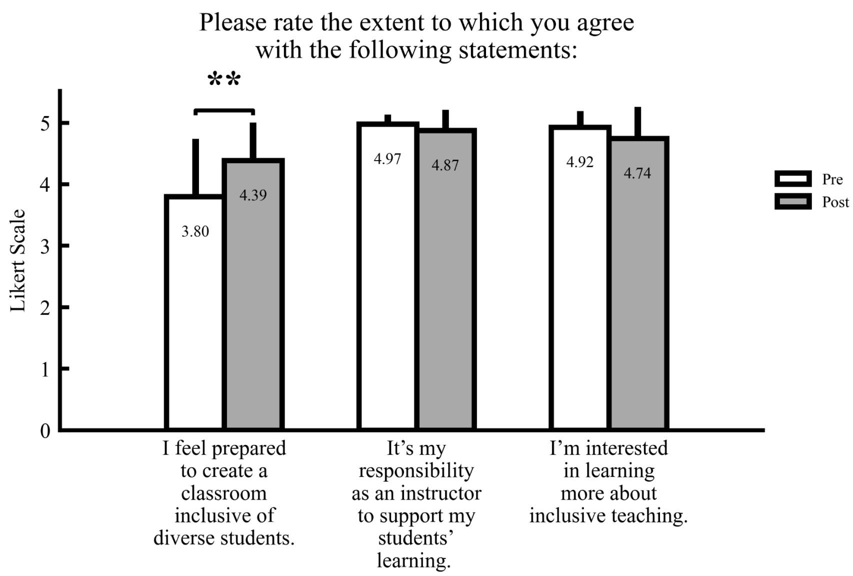

Figure 12. Self-reported participant preparedness and interest in using the strategies taught in the course for their current and future teaching. Samples were taken before (n=40) and after (n=31) taking the course using a 5-point Likert scale (1: Strongly disagree; 5: Strongly agree). Statistical comparisons were made with the Mann-Whitney U test (**: p<0.01).

Discussion

In this work, we created and taught a peer-led pedagogical course centered around equitable teaching practices and generalizable communication skills that would properly equip graduate TAs for success, both in their TAships and future careers. We took a student-centered approach in creating the class with the goal of increasing participant self-efficacy as educators and building a community of educators in our department. Our overall course design was composed of **(a)** choosing topics curated from education literature, **(b)** lesson planning using evidence-based strategies for effective learning, and **(c)** creating a community-focused constructivist classroom structure of experienced graduate students as primary instructors and utilizing BioE department faculty members as discussion participants. Survey data strongly indicate that the course empowered participants to achieve the course learning objectives. Participants reported an increased mastery of pedagogical theory and practices, including active learning, inclusive teaching, and more. Further, through the final project, participants solidified their knowledge by applying course content to their own areas of interest.

Previously, our department offered just two opportunities for graduate TA training in the form of a 1.5-hour departmental orientation and a 4-hour schoolwide TA training. Based on participant feedback, this course filled a previously unmet need in the Bioengineering graduate curriculum. One participant in 2022 wrote, “I was grateful to have this course before TAing and hope the department continues to provide training, tools, and conversations that equip us to become excellent teachers, mentors, and educators.” Indeed, participants reported high levels of importance for this pedagogy course as it pertains to their current work in comparison to other required department courses and unrestricted electives. There may be a selection bias at play here, where given that enrollment in this course was voluntary, graduate students who are motivated to improve their teaching skills and pedagogical awareness may be more inclined to value the course as important. The Dunning–Kruger effect, a cognitive bias in which people with limited competence in a particular domain overestimate their abilities, could also be relevant to consider in participant responses of self-efficacy. Taken in the opposite direction, graduate students who are already critically aware of their own teaching limitations, enough to voluntarily take a voluntary pedagogy course, may be underestimating their own abilities.

Though many departments and institutions require GTA training courses, our course is not currently required. This raises an interesting set of questions and opportunities for future consideration such as, “Within our own department, do GTAs that take our pedagogy course show increased self-efficacy in teaching as compared to those that do not after their first TAship?” or “Can we measure any differences in impact course participants have on their future students as compared to GTAs who have not taken our course?”

For future directions, we plan to evaluate the effect of the course on graduate TA preparedness by expanding data collection along three key dimensions: (1) Sampling a greater proportion of graduate students in Bioengineering (including non-course participants as a control), (2) evaluating content mastery of pedagogical knowledge and skills covered in the course via written and oral assessment, and (3) implementing longitudinal surveys to determine the long-term impact of expanded pedagogical training on TA effectiveness and other academic or professional roles that benefit from transferable teaching skills.

For (1), in the Spring of 2026, we will implement this course with a new cohort of graduate students; this will provide a greater sample size of course participants. We also plan on surveying graduate TAs in the department that do not take our course to serve as comparative controls to demonstrate the course's effect. Given that all course participants self-selected to take the course (i.e., the course is not a departmental requirement), there may be bias introduced in the self-reporting.

For (2), we believe that evaluating content mastery of pedagogical knowledge and skills covered in the course beyond self-reported levels of comfort utilizing alternate forms of assessment will increase the rigor of our tests. By comparing mastery of pedagogical content and skills between course participants and non-participants, we will be able to more effectively assess the impact of our course in comparison with the baseline graduate TA training requirements. This quantification of graduate student expertise in pedagogical practice, a skill set that is essential for students pursuing faculty careers, may also be a useful metric for graduate training more broadly. In the initial design of the course, we chose to move away from traditional assignments and assessments (such as quizzes and tests) to maximize the accessibility of the course. Given that our course participants are graduate students with research responsibilities, reducing the time burden for this course was a top priority. Still, we believe that utilizing a limited number of ungraded assessments will increase opportunities for active recall and spaced repetition without a significant increase in participant time burden.

For (3), one of the driving motivators in the inception of the course was creating more opportunities for graduate students to develop professional skills relevant to their future careers. Thus, we will employ longitudinal surveys to track course participants not just after their first TAship, but also after their experiences as mentors and leaders through and beyond graduate school in academia, industry, or elsewhere. We are currently awaiting IRB approval on a survey protocol to recruit former course participants and non-course participant graduate students in BioE to look at post-intervention data.

In summary, we designed a course to equip graduate TAs with the pedagogical skills and knowledge necessary to be effective educators and communicators, and our evaluation strategy to date has focused on assessing this goal. Future data collection will provide additional evidence regarding course efficacy and whether such training should be required. We hope that this work can help catalyze the implementation of similar pedagogy courses across departments and institutions, for building a community of equitable and effective educators, and continuing efforts to improve and measure the pedagogical preparation of graduate TAs.

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Author contributions: W.Y., C.M., A.P., and A.R conceptualized, co-led class sessions, analyzed and interpreted data, and wrote the manuscript. K.M. and M.F. contributed to iterative course design, co-led class sessions, and analyzed and interpreted data. A.M. and R.V. provided feedback on survey design and methodology. All authors discussed the results and commented on the manuscript.

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Materials availability: Course materials (lecture slides, lesson plans, handouts) are available by email request to authors.

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Appendix

A1. Final Project Description

Project Overview

The final project provides a structured way for participants to **draw connections between course topics** and make a concrete **plan** for applying learned skills in the future. You are encouraged to choose a communication-related situation or role that: **(1)** is **reliant upon or improved by** effective communication and **(2)** will be **meaningful and useful** to you. See the "**Example Project Topics**" section below for ideas!

The project is broken into **weekly modules**, allowing participants to make progress on the project each week to reduce the burden on students during weeks 8-10 without reducing the impact of the exercise. The **scope of the project** and **means of presentation** are personalizable, guided by the following learning goals.

Project Learning Goals

Through completion of this project, participants will…

- **Internalize** the value of equity-centered teaching practices for improving communication efficacy.
- **Identify** an area of life or specific role in which effective communication (or, more specifically, effective teaching) will help them achieve their personal or professional goals.
- **Describe** their vision of effective and equitable communication/teaching in that area of life or role (their communication/teaching/mentoring philosophy).
- **Design** a communication/teaching/mentoring artifact that uses course concepts to realize their vision.

Final Project Checklist (Rubric)

All projects, regardless of the topic and means of presentation, should include the following:

- **Project Topic:** A clear description of the selected project topic.
- **Motivation:** Explanation of why you chose this topic and means of creation.
- **Course Topics:** Synthesis and application of at least three (3) course topics and justification for why you selected these course topics to use for your project.
- **Support:** At least three (3) primary sources that present evidence-based best practices and aid you in creating your project. Look to Canvas for a starting point!
- **Project Deliverable:** The bulk of your project! The topic-specific aspect of your project. See "Means of Presentation" for examples of forms this might take.
- **Self-Reflection:** A reflection exploring what you learned through completing this project. How did this project help you gain a deeper understanding of teaching and communication? What would you do differently next time

Example Project Topics

Example ideas for this project include (and are certainly not limited to):

- **Teaching:** Design a lesson plan for a discussion section, final review, or office hour you might lead as a TA. How will you engage students? How will you divide your time equitably between predefined and student-requested topics? How will you apply feedback to guide students?
- **Teaching:** Imagine that you are asked to consult on course redesign for a class that you took but did not love. Write a proposal that outlines the current class structure, identifies strengths and weaknesses based upon student data, and makes actionable suggestions for improving one (or more) metrics of class success. Be sure to support your suggestions with evidence and references from the literature (e.g., resources used in course slides).
- **Mentoring:** Design a 10-week plan for mentoring a rotating graduate student or summer undergraduate student in your lab. How could you apply feedback strategies to help them achieve their goals? How will you ensure that you set -- and revisit -- reasonable and actionable goals? How will you communicate with them and teach them the ins and outs of your field?
- **Mentoring:** Imagine that you are a manager who is informally mentoring a recruit at work. How might you help the mentee set goals and devise a plan to achieve those goals? How might you help them to feel included in the workplace community? How might you apply ideas around rubrics and expectancy to a workplace setting?
- **Leadership:** Imagine that you are the chair of an engineering department at a research-focused university. What steps might you take to work towards equity and inclusion within your department (could be focused on admissions, curriculum design, or community-building)? Consider how you might formulate and define a plan, delegate roles/responsibilities, and provide feedback to your team.

A2. Final Project Titles from 2022 - 2025

A Briefing on Course Design for Mathematical Bioengineering Classes	Mentorship Workbook: Starting Research for High School & Community College Students
A Guide for STEM Instructors: Teaching English Language Learners	Micro-teaching for self-reflection
A guide to exploring a lab outside your realm of expertise	My Equitable Mentorship Plan
A Notion-Based Mentorship Planner and Journal	My Personal Teaching Philosophy
A Quick Guide to Being a TA	Navigating Graduate School Applications Workshop

A Sneak Peek into the EE Graduate Program	On mentoring researchers in a lab
Balancing Rigor & Accessibility in Introduction to BioE	Optimizing research experiences for rotation students and undergraduates
Beyond Traditional TA Office Hours: A Blueprint for Boosting Efficiency and Engagement in Bioengineering Education	Planning an Acapella Camp
Chinese Exchange Students Program Pre-departure Camp: Goal Setting Workshop	Presenting For YOU: Clear and Effective Communication Guides Feedback
CoLab RPG	Quarter-long TA Salon
Creating more inclusive math classes	Rethinking the Discussion Section
Culturally Responsive Teaching in Mexico	Rotation student mentorship guidelines
Developing risk-tolerance and comfort with the unknown	Self-Written Assessment Guide (SWAG) for research mentees
"DNA" Student Toolkit: Develop, Nurture, Advance	Statement of Teaching Philosophy
Dr. Applebee's Tricks for Exquisite Teaching!	STEMspire Speaker
Entering US Grade School as Newly Immigrated Student	Student-Centered Engineering TAs
Feedback in My Teaching Philosophy	Summer REU Mentorship Plan
Giving a mathematical modeling tutorial	Syllabus for a Finite Element Analysis Class
Gradient Descent (**αΣμρ**)	TA Teaching Simulator
Infographic on Lab Culture and Best Practices	Teaching Cheatsheet
Interactive teaching flowchart	The Art of Managing Upwards
International students in a US higher education STEM classroom- challenges and opportunities	Transition to Residency in America
Lab Learning: pedagogy at the bench — and other non-conventional mentorship settings	Undergraduate Research Mentee Training Playbook
Letter to a Summer High-school Intern	Understanding and Overcoming Procrastination
Mentoring and managing for a lab project	Weekly Surveys for Science Olympiad Students
Mentorship Plan for Summer REU	