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Reverse Engineering Professional Development for Graduate Students: Applying Backwards Design Principles to an Introductory Inclusive Teaching Training Program

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Abstract

This paper describes the development and implementation of an inclusive teaching training program for STEM graduate students using backwards design principles to address persistent attrition, equity, and inclusion challenges. While graduate student teaching training opportunities have increased in recent years, we identified a critical gap in inclusive teaching preparation for teaching assistants and instructors of record in STEM fields. Our three-session workshop series applies a novel 'reverse engineering' approach, starting from learning goals and working backwards to instructional content.

In the workshop series we created, we foster a shared understanding and application of terminology and definitions, explore inclusive teaching practices, and prepare students for facilitating difficult conversations and situations in teaching. These are presented in a sequence of three 90-minute sessions with facilitated content and breakout small-group discussions. The two later sessions also have two discussion scenarios each on difficult teaching situations for students to think through and problem solve in small groups.

The content is important; however, the novelty of this programming is the development process. We reverse engineered the development of this program (applied the educational technique of backwards design), starting from learning goals and outcomes, back to activities and evidence of learning, then finally back to instructional approaches and content. As a particular novelty and also advantage, this programming also maps onto and aligns with the professional development learning outcomes for more comprehensive faculty programming around broadly inclusive teaching. To our knowledge, this program is the first of its kind in inclusive teaching training for STEM graduate students, particularly with the "reverse engineering" development approach *and* alignment with separate faculty professional development programming.

This work is a result of a highly productive collaboration between the teaching and learning center and the college of engineering's diversity office (now called the office of outreach, student success and engagement). The content developer/facilitator, from the teaching and learning center, also holds a PhD in engineering.

We have offered this program three times (each fall and spring semester since Fall 2023) to enthusiastic reception. With each offering, we continue to assess and will report on the program, outcomes, and efficacy, with positive programmatic assessment already observed. As part of this paper/presentation, we seek to share not only the methods and our observations, but also the content (learning outcomes, slides, advertising/recruiting, and program promotion ideas) so others may adapt and apply this program at their own institutions without the need to recreate from the beginning.

Background and Context

The STEM fields continue to struggle broadly with attrition, equity, and inclusion issues across many -- often intersectional -- identities and backgrounds. These challenges have economic implications that extend beyond academia; recent workforce analyses show STEM jobs are projected to grow 10.4% between 2023-2033, nearly three times faster than non-STEM positions, with potentially 2 million positions unfilled due to skills gaps by 2025 [1]. The NSF's comprehensive 2023 report on diversity in STEM further highlights persistent disparities, particularly for women and underrepresented minorities [2]. These findings underscore the importance of preparing graduate students to create inclusive learning environments that support success for all students. Rates of leaving the STEM fields are estimated at approximately 50% [3], with persistence in the fields reportedly stagnating in the 2010s [4]. Attrition continues from undergraduate through the graduate level (Satterfield et al., 2018) and faculty roles [5]. Even beyond attrition, changing career paths within the STEM fields presents a compelling phenomenon and indicates lower potential motivation and persistence at the undergraduate level [6] and beyond [5]. Trends across multiple, potentially intersectional, identities impact career persistence, inclusion, and trajectories, for example, across race [7], [8], [9], [10], gender identity [7], [10], [11], sexual orientations [12], socioeconomic status [13], first generation college student status [14], among others.

The opportunities for graduate student teaching training have been historically lacking [15] – and may still be lacking in some areas [16] – though more recently some increases in opportunities have been documented in recent years [17]. Importantly, inadequate teaching is reported as a major driver for student attrition from STEM programs [4]. Considering that many graduate students in the STEM fields serve as graders, teaching assistants (TAs), or instructors of record at some point during their studies, broadly addressing the need for improved STEM teaching would also include a need for greater training of graduate students [18]. Engineering and computer science TAs serve in many roles and generally are considered one of the “front-lines” for teaching and learning at many institutions, yet they have little experience in educational strategies or training to grade student work [19]. Specifically at our institution, we identified a desire for focused training on inclusive teaching for graduate student teaching assistants, graduate student instructors of record, and/or those seeking these roles in the future.

Professional development related to teaching and learning for instructors positively impacts these practices and, more widely, the learning environment and experiences for students [20] and specifically, their students’ learning [21]. This is similarly indicated for graduate student instructors [22]. Yet, the application of research-based teaching strategies and approaches that is a key need in engineering education [23] is impossible to do when those tasked with leading the classrooms have little to no training. Particularly when disparities in persistence and retention across demographics are present in the STEM fields, as noted previously, training particularly in

evidence-based inclusive teaching approaches may be useful for graduate student instructors/TAs [24]. Further, the graduate student audience creates a unique group, as these individuals have many competing priorities and demands on their time. Providing professional development for this audience seems to be a pressing need, but we also recognize that it must be aligned well with this audience's competing factors (e.g., needs, time availability, modality, and similar) [25].

Our Programming

We developed a comprehensive program for faculty instructors to support their professional development, including learning outcomes and spanning a range of modalities to interact with content. This approach includes strategic planning and implementation around leveraging campus partnerships and engaging in multiple ways with institution-wide initiatives (e.g., undergraduate core curriculum, community engagement, and similar [26]).

While we identified the need for graduate student professional development, we made the conscious decision to have it align – in both smaller duration and in part – with the suite of programming and level-oriented learning outcomes we designed for faculty professional development. As the development of the faculty programming is not the focus of this article, we limit our discussion here to the overview of a multi-level, ongoing professional development program about broadly inclusive teaching for faculty and the learning outcomes for levels 0, 1, and 2 shown in Table 1. Importantly, for both faculty and graduate student programming, the learning outcomes may be met in several different workshops. This aligns with the general expectations of programmatic curriculum mapping and visual demonstrations [27] rotated here to a horizontal presentation, as well as aligned with strategic planning efforts [28] and curriculum outcomes [29].

Table 1. Programmatic learning outcomes for the graduate student mini-course shown by session (shading highlight indicates presence, as is standard for curriculum mapping (e.g., [27])) mapped against the three levels of the faculty programming learning outcomes. As shown, individual sessions may include or reinforce learning outcomes in other sessions.

Faculty Programming Learning Outcomes	**Graduate Student Programming Learning Outcomes**		
	Session 1	**Session 2**	**Session 3**
Level 0: Recall terminology surrounding broadly inclusive teaching practices			

Level 0: Summarize broadly inclusive teaching techniques in conversation with peers/colleagues			
Level 0: Articulate your own "why" for engagement in this space			
Level 1: Acknowledge that there are historical and contemporary factors impacting the need for deliberately inclusive teaching practices to support all students			
Level 1: Summarize broadly inclusive teaching practices applicable to participant's class/discipline			
Level 1: Apply terminology and concepts related to broadly inclusive teaching in conversation, classrooms, or syllabus development			
Level 1: Implement iterative, stepwise advancements (plan-implement-evaluate) in broadly inclusive teaching strategies in their own courses or academic programs			
Level 1: Develop and critique inclusive teaching goals for self/courses/academic programs, as applicable			
Level 2: Describe a commitment to continued development and individual personal/professional growth in broadly inclusive educational practices			
Level 2: Recognize the historical and contemporary factors influencing society and education today			
Level 2: Develop and apply broadly inclusive teaching practices			
Level 2: Evaluate iteratively applied inclusive teaching practices and goals (plan-implement-evaluate)			

Table 1 displays the distribution of fully mapped learning outcomes across the sessions of the Inclusive Teaching for STEM Graduate Students Mini-Course sessions to the first two levels of the faculty programming learning outcomes. We note that the final Level 1 learning outcome of

developing and critiquing inclusive teaching goals for self/course/academic programs, as applicable, is not indicated for the graduate student programming, as it is only met in part through the sessions. In the sessions, we do include substantial opportunities for students to share experiences and ideas for how they do – or might – implement broadly inclusive instructional strategies. This level of sharing partially maps to the learning outcome for the faculty programming who are expected to articulate more clearly and level-up their analysis through critique of the teaching strategy.

The graduate student mini-course is advertised through listserv(s) and/or paper postings on bulletin boards with additional information:

- Open to graduate students in STEM-related programs
- Continue to develop your inclusive teaching skills to support all students in your classes
- Attend 3 workshops in [session month/year]
- Eligible to earn an Inclusive Teaching for STEM Graduate Students Mini-Course Certification

All sessions are 90 minutes, including both content delivery (generally 50 minutes total) and small group breakout discussions (generally 40 minutes total, broken into 5-10 minute individual breakout sessions). Please note that while the sessions are titled "classroom," the instructional modality is defined broadly and teaching techniques and strategies for in-person, hybrid, and online/asynchronous courses are discussed.

Our Roles and Institutional Positionality

This work is a result of a highly productive collaboration between the teaching and learning center and the college of engineering's office of outreach, student success, and engagement (formally the office of diversity, outreach, and inclusive learning). The content developer/facilitator is the assistant director in the teaching and learning center and also holds a PhD in engineering. This programming was developed at a large research university in the Mid-Atlantic region of the United States that is considered a minority-majority institution. The political context in the state is complex and the governor directly appoints the trustees for the institution.

Methods: Backwards Design and Development

The content, learning outcomes, and session descriptions may be interesting; however, one aspect of the novelty of this programming for graduate students was the development process. We essentially *reverse engineered* [30], [31] the development of this program by applying the educational technique of backwards design [32], [33]. With this process application, we hope

that other institutions can make use of the content, overall program, and resources that we have developed by also reverse engineering and applying what we have developed as it is useful to their local setting [34].

In our development process, we sought to backwards design from our desired learning outcomes and goals. Backwards design includes starting from student learning goals and outcomes using a design-based approach [32], [33] generally back to activities and evidence of learning, then finally back to instructional approaches and content. This aligns the educational design approach with an engineering approach [33] and an engineering education style. Importantly, it is considered "backwards" because it contrasts with the *usual* approach of learning design that simply covers a certain number of chapters of a textbook, for example, and moves *forward* to what the students might learn from the content [33] or perhaps starts with the syllabus and again moves *forward* from there [35]. Applying backwards design is useful at both the course [36] and programmatic [37] levels for academic programs. This value is similarly reflected here with the programming for faculty and graduate students. Further, explicitly linking engineering design principles and pedagogical approaches, including the practice of teaching and learning, provides added value in both theory and implementation [38].

Novelty of Alignment and Professional Development Curriculum Mapping

As a second specific point of novelty, this programming also maps onto and aligns with the professional development learning outcomes for more comprehensive faculty programming around broadly inclusive teaching. While several institutions have recently implemented inclusive teaching programs for graduate students, such as the Inclusive Course Design Institute at the University of Texas that teaches backwards design principles alongside Universal Design for Learning [39], our program is distinctive in its dual innovation: the reverse engineering development approach *and* deliberate alignment with faculty professional development programming. Recent applications of backwards design in STEM education have shown promise in specific disciplines, such as molecular biology course-based undergraduate research experiences [40] and chemistry laboratory instruction [41], but few programs have applied this approach specifically to graduate student inclusive teaching preparation across STEM fields. We find this particularly useful, as we are providing professional development to individuals (both faculty and graduate students) in instructional or instructional support capacities that have similar content and learning goals. This is designed purposefully to create a unified approach to broadly inclusive education to support all students and faculty.

Inclusive Teaching for STEM Graduate Students Mini-Course

In this workshop series for graduate students, we create a shared understanding and application of terminology and definitions (session 1), explore inclusive teaching practices (all sessions), and prepare students for facilitating difficult conversations and situations in teaching (sessions 2 and

3). These are presented in a sequence of three 90-minute sessions with facilitated content and breakout small-group discussions. Session two and three also have two discussion scenarios on difficult teaching situations for students to discuss and problem solve in small groups. The titles and potential advertising descriptions for each of the sessions is included in Table 2.

Table 2. Session titles and descriptions for each of the three sessions of the Inclusive Teaching for STEM Graduate Students Mini-Course.

Session Number	Session Title	Description
1	Developing More Inclusive Classroom Spaces	Are you ready to integrate inclusive teaching throughout your instructional spaces? Would you like to explore techniques and build tangible plans for your classes? This is where that journey begins. In this workshop, we will explore some of the definitions and terms often found in conversations about creating more inclusive classrooms. We will work together to advance our individual abilities in broadly inclusive teaching and learning to support all students. At the end of the workshop, we will have developed familiarity with concepts and terminology, explored deliberately inclusive classroom activities, and set one or two manageable goals for our classes.
2	Important Conversations in the Classroom: Preparing Your Course and Yourself	Do you have strategies to prepare yourself and your students to handle difficult conversations? This could be when you are having difficult conversations about topics like race, sexuality, religion, politics, or similar. These situations also could result from a discussion comment that makes a student or group uncomfortable or might even be about grades. In this workshop, we will discuss how to design (or redesign) your course and prepare yourself to facilitate important or "hot topic" conversations in the classroom. Background information on how to design the course and prepare for facilitating important conversations in the classroom will be provided. This workshop is applicable to teaching assistants/instructors across all disciplines for facilitating important conversations, whether or not their designed course topics include socially pressing issues.
3	Important Conversations in the Classroom: Handling Situations in the Moment	Are you prepared to handle difficult discussions and charged situations in the classroom in the moment? Do you usually think of things later that you wish you would have said or done? In this workshop, we will prepare and practice how to handle important and potentially tense classroom conversations in the moment. Our focus will be on how to support everyone in the classroom – including yourself – during tense times. We will discuss and practice several teaching approaches. This workshop is applicable to teaching assistants/instructors across all disciplines for facilitating

		important conversations, whether or not their designed course topics include socially pressing issues (like race, gender, religion, politics).

Results and Observations

While the purpose of this paper is to describe the backwards design of the professional development program for STEM graduate students, and particularly the alignment with broader faculty programming around inclusive teaching practices, we present here a brief overview of the application through selected results and observations as a type of proof-of-concept. Essentially, we hope that our content and observations may be useful as a starting point example for other institutions to support their graduate student instructors. We present all information here in a programmatic assessment style, not a human subjects research approach (see IRB review section statement below). This means that we are observing and providing a general research assessment of the program as implemented. We encourage others to adapt this work and assess efficacy and transferability in their own institutional settings.

We have offered this program three times (each fall and spring semester since fall 2023) to – what we feel personally was – enthusiastic reception from both faculty and graduate students. With each offering, we continue to assess and report on the program, outcomes, and potential efficacy, with positive programmatic assessment already observed. Table 3 shows the number of finishers and total attendances for the three sessions. We use this metric to gain an initial sense of overall engagement with the programming, even when individuals may not finish. Several individuals across sessions also may have attended all three sessions but not completed our final form that asked for how they wanted their name on the certificate and several short reflection questions, so they are not listed as finishers in this table.

Table 3. We share the approximate number of finishers and total attendances for each of the sessions.

Program	Finishers	Attendances
Fall 2023	10	27
Spring 2024	21	34
Fall 2024	8	21
Spring 2025	28	64

Please note that the data in Table 3 may be seen to indicate a potential lack of attendance-to-completion conversion. We posit that this is not reflective of lack of engagement or interest, but rather of varying schedules and our *direct encouragement* to attend what may be possible, even if that means not finishing the program at that time. We also suggest that participants may pick up sessions at different times across program offerings to make it as flexible as possible. This approach aligns with meeting the audience where they are, a specific need we noted for the

programming. As such, some who may have attended selected sessions may yet complete the program. The underlying motivational principle here is that *some engagement* with inclusive teaching content is more beneficial than no engagement with the content and that the completion certificate on its own is not the most meaningful part of the process.

Programmatic Assessment

Among the participants counted in Table 3, we had graduate students from both the college of engineering and computing and also the college of science attend. This program is deliberately "STEM-focused," so it is open to both colleges. As such, the attendances are from a wide range of departmental backgrounds within the STEM fields.

At the end of the three-session program, we asked students who had completed the sessions to fill out a form. They were asked organizational details, such as their name as they would like it displayed on the certificate, their college/department, their agreement that they fully met the requirements of the program for attendance and engagement (which we also verify from our records), and four additional open response questions:

- What is one thing that you learned about inclusive teaching that was new to you or surprised you?
- What are you taking away from this mini-course that is most valuable to you as a GTA/instructor in STEM? (For example: What did you learn or find most useful?)
- What is something that you would like to learn in the future about inclusive teaching? (For example, a topic, workshop focus, or type of professional development program)
- Is there anything else that you would like to share with us?

We use the responses to the questions listed above to help us continue to shape the program to meet the needs of graduate students. During the program registration, we also asked students if they were current or aspirational graduate student teaching assistants (TAs) or instructors of record. Based on the responses, we believe that many graduate students may be using the program to prepare themselves for future teaching, as aspirational TAs or instructors of record. This program may make them more competitive for a limited number of funded TA or instructor positions.

Programmatic Assessment: Methods

From our casual thematic analysis [42] at a programmatic assessment-level for qualitative analysis [43] and text interpretation [44] we have observed that students responded generally positively to the programming. We acknowledge the potential for bias in "positively," as students are responding to questions asked as part of the form to receive their certificate. Completing the form was needed for the certificate, but there were no "right or wrong" answers, for example. However, other anecdotal evidence such as returning for sessions two and three to complete the program indicates at least a minimum level of interest in persistence and

engagement with the topic. Overall, we posit a perspective that these graduate students may be interested in this topic of broadly inclusive teaching and may view professional development in this space as beneficial to the implementation of their role as a grader/teaching assistant/instructor of record and/or view completion of a professional development program as advantageous to their career.

Programmatic Assessment: Student Responses

We highlight selected general responses in Table 4 to the first two questions from our programmatic assessment completion survey (listed above).

Table 4. Overview of selected responses to questions one and two from the post-course survey.

Q1: What is one thing that you learned about inclusive teaching that was new to you or surprised you?	• Setting classroom ground rules/community guidelines • How to approach and navigate difficult class conversations and situations • Broad aspects of diversity, as well as definitions for inclusive teaching-related terms • The multiple roles of an instructor (e.g., content, guidance, shaping conversations, creating the class environment) • Specific inclusive teaching strategies • Discussing scenarios with peers/colleagues
Q2: What are you taking away from this mini-course that is most valuable to you as a GTA/instructor in STEM?	• How to be prepared as well as possible for difficult situations in teaching • Expected policies and practices (seeking support, documentation) • The importance of inclusion as an active practice in the STEM fields • Students' perceptions and responses to instructors • The instructor's role and strategies for shaping the classroom environment (actively working to create a space for belonging)

We used the responses to the third question to continue shaping ideas and plans for future programming, both for graduate students and new faculty. As such, the responses to the third and fourth questions are less applicable to the focus of this paper and are omitted for brevity. The responses to the first two questions above note specific takeaways related to the content and activities of the three-workshop mini-course. These include specific skills and teaching strategies that may foster more inclusive spaces within individual courses and build graduate students' skills as they move into the next stages of their careers.

Limitations and Future Directions

We acknowledge that this paper is not able to cover all potential aspects of teaching and learning development, implementation, and assessment of a new teaching and learning professional development program for graduate students. In this, we purposely chose to focus on the development process, including specifically the backwards design as part of our efforts to "reverse engineer" workshops to meet the needs of our graduate students and our institution, as well as the mapping and alignment with faculty professional development programming. In this work, we include the process and details for the development, as well as selected results from a general programmatic assessment [34].

In the future, we look forward to opportunities to track potential outcomes or impacts beyond student-reported programmatic assessment in closing surveys. This likely would include research specifically on any potential pre-/post-program changes in students' responses to their teaching assistant/graduate student instructor, or perhaps potential changes in the likelihood of a graduate student being selected or not to TA or teach a course based on their completion of the program. We also note particular potentials for assessing graduate students' reflections on the program in additional follow-up surveys or interviews, as well as understanding faculty member and administrator responses to students' participation in the program. Unfortunately, these were outside of the context of this particular paper. We hope that the initial development, planning, and programmatic assessment here provide useful content to other institutions, and as such, we are sharing the process (in this paper) and the content (in the next section) for others to adapt for their own use at their institutions without – as the saying goes – reinventing the wheel. We also look forward to connecting with colleagues in person at the conference to provide additional information, as well as build new connections and follow up to support graduate student teaching assistant and instructor training broadly.

Outlook and Materials Sharing

As part of this paper/presentation, we seek to share not only the methods and our observations from an initial programmatic assessment, but also the content (learning outcomes, slides, advertising/recruiting, and program promotion ideas) so others may adapt and apply this program at their own institutions without the need to recreate from the beginning. While the learning outcomes are shown in Table 1 and the descriptions for the sessions in Table 2, and the development process and selected programmatic outcomes are detailed in the paper above, we provide additional useful content (e.g., workshop slides, advertising information) by link during the presentation and look forward to connecting with colleagues via email.

Conclusions

We developed an inclusive teaching mini-course for graduate students in STEM fields. Based on our research in the approach of a programmatic assessment, we continue to assess that the time

investment and outcomes may be beneficial for the graduate student participants and meet specific needs for promoting student learning in engineering.

Novelty

To the best of our knowledge, this is the first inclusive teaching program of its kind to be reverse engineered as it applied the process of backwards design and also parallels the faculty professional development program learning outcomes by partially mapping onto the larger faculty program. This novelty aligns the professional development learning related to broadly inclusive for potentially everyone in an instructional type of capacity.

Sharing

We developed this program for use at our institution, but hope that our development process and observations will be useful to others. Our goal is that the materials shared for the content may be adapted to the setting at other institutions for the greater good of graduate student learning across colleges of engineering broadly and the good of teaching and learning in engineering as a whole.

IRB Disclosure

This work was submitted to the university Institutional Review Board (IRB) and was determined to not be human subject research. This determination is of record and submitted as STUDY00000234.

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