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A Pilot Study of Supporting GTA Professional Development and Educator Identity in Engineering

Gokce Akcayir[1], Janelle McFeetors[1], Mijung Kim[1], Kerry Rose[1], Marnie Jamieson[1], Kristian Basaraba[1], Qingna Jin[2] & Duncan Buchanan[1]

[1] University of Alberta, Canada, [2] Cape Breton University, Canada

Abstract: Graduate teaching assistants (GTAs) significantly contribute to the learning and experiences of undergraduate students. Thus, supporting and enhancing GTA pedagogical knowledge and competencies can improve the learning experiences of undergraduates. Towards this goal, a discipline-specific pedagogical professional development program was created for GTAs in the Faculty of Engineering at a Canadian university. This case study explores the perspectives of participating GTAs, including how they engaged in learning about teaching, what they learned, their emerging educator identity formation, and the challenges they faced during the program. Situated learning theory informed the analysis of participant interviews and focus groups. Findings indicate that GTAs appreciated the situated and embedded nature of the program, reporting limited prior familiarity with pedagogical tools and practices and their application. Results also highlight the need to align GTA roles and responsibilities, providing opportunities to put their learning into practice with the pedagogical knowledge they developed in the program.

Keywords: Teaching assistants; professional development; educator identity formation; community of practice; engineering education; situated learning
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Introduction

Graduate teaching assistants (GTAs) play a significant role in shaping the learning experiences of undergraduate students (Chen Musgrove & Schussler, 2020; Gardner & Jones, 2011). However, their potential as higher education practitioners is often hindered by a lack of opportunities and support systems in their preparation (Verleger & Diefes-Dux, 2013). GTAs are expected to perform various pedagogical practices, including lab instruction, lab demonstrations, and grading student work while often experiencing minimal opportunities to fully comprehend the implications and rationale behind these activities. When opportunities for learning to teach do exist, they often fail to address the specific needs of different disciplines, despite the clear necessity for discipline-specific preparation (Bubbar, Dimopoulos, Korpan, & Wild, 2017). Effective educators must possess not only subject matter knowledge and expertise but also pedagogical content knowledge that enables them to employ discipline-specific instructional strategies effectively (Fernández-Cézar, Henar, Francisco, & Cristina, 2020; Lee, 2019). GTAs typically serve as a major point of contact for undergraduate students in higher education and as such have been termed the “first line of defense” toward improving educational experiences in universities (Nicklow, Marikunte, & Chevalier, 2007, p.89). As GTAs often have a high level of interaction with students and as they often act as agents of the course instructor, especially in large enrollment courses, any positive impact on GTAs’ teaching practices could directly improve students’ learning experiences (Hsu, 2019; Verleger & Diefes-Dux, 2013). GTAs often have little or no preparation for their roles as educators and as such may lack awareness of the significance of their role in higher education. Due to this lack of awareness and limited support, they often rely on teaching approaches they have encountered as students, or those of their peers, whether those approaches have been successful or not (Gardner & Jones, 2011). For

this reason, improving GTAs' pedagogical knowledge and skills could be seen to be a crucial step towards enhancing teaching practices in postsecondary education.

This study introduces a professional development (PD) program intended to provide GTAs in the Faculty of Engineering with opportunities to reflect on and learn pedagogical approaches. The program intent is to move beyond PD as a passive, instrumental approach to gaining teaching skills toward professional learning (PL) as actively and deliberately enhancing one's teaching and understanding of teaching in way that is "continuing, active, social, and related to practice" (Easton, 2008; Webster-Wright, 2009, p.702). For clarity, we use "PD program" throughout to refer to the program offered to GTAs that engaged them in professional learning about postsecondary engineering pedagogy.

As part of a project aimed at enhancing undergraduate pedagogy in the Faculty, a discipline-specific PD program for engineering professors was developed by an academic center with a focus on mathematics, science and technology education in a Faculty of Education located within the same university. Subsequently, this pedagogical PD program was adapted for engineering GTAs, with an aim to enhance and support their professional learning. This pilot study was conducted to investigate the participants' experiences in this program. The specific research questions that guided this study were:

- What features and content of the program did GTA participants highlight/recognize as comprising their opportunity to learn about teaching?
- In what ways did GTA participants begin to form an educator identity through their experiences in the program?

Supporting GTAs' Professional Learning about Teaching and Learning

In most universities, GTA preparation for teaching is conducted at the institutional level and is often general and not discipline-specific (Lee, 2019; Luft, Kurdziel, Roehrig, & Turner, 2004). Additionally, it is often limited in duration, typically lasting for one day or less (Lee, 2019). Recognizing the lack of attention to development of GTAs in higher education institutions, researchers have been exploring various ways to provide pedagogical support to GTAs. Sharpe (2000) created a GTA training program conceptual framework consisting of teaching and discipline knowledge, teaching skills and accreditation. Sharpe also identified three critical elements GTA training programs should have: support from departments, involve learning in groups, and promote reflection on learning. Reeves et al. (2016) created a conceptual framework categorizing outcome, contextual and moderating variables of GTA professional development (PD) programs to shed light on the evaluation and research surrounding GTA (PD) programs. Within this framework, important design variables in preparing GTAs for teaching responsibilities were identified as the content, activities, and structure of the program (Reeves et al., 2016) echoing content and activity elements of Sharpe's stepped conceptual framework and including moderating variables as design factors related to the particular circumstances of

GTA and their role. Slaughter et al. (2023) applied Sharpe's key principles (department training, faculty training, and accreditation) to the development of a GTA program piloted in 2016 and now offered annually to over 950 GTA participants across nine departments in the Faculty of Science and Engineering at the University of Manchester. The program consists of four themes: pedagogical knowledge, personal development, practice and professional development.

Content

In terms of content of pedagogical PD programs, the importance of discipline-specific GTA preparation has been recognized (Chadha, 2015; Hardré & Burris, 2012; Lee, 2019; Sharpe, 2000; Slaughter et al.,2023). Effective educators need to possess not only subject knowledge and pedagogical expertise but also pedagogical content knowledge (PCK) specific to their discipline (i.e., science, engineering, humanities) that enables them to employ appropriate instructional strategies effectively (Shulman, 1986). Each discipline has its own culture and practices, along with characteristics related to the nature of the discipline (Mintz, 1998; Serow, Van Dyk, McComb, & Harrold, 2002). Thus, teaching in a professional capacity requires the instructor's understanding of subject matter knowledge and their understanding of the practices that are effective in teaching the knowledge from the specific discipline (Shulman, 1986). Discipline-specific PCK development also helps to make the professional learning directly context-focused (Nelson & Brennan, 2021). Therefore, in engineering, it is important that GTA preparation should be tailored to focus on engineering-specific pedagogies.

Many pedagogical PD programs for GTAs have content limited to specific aspects of teaching (even within a discipline) or content that targets a subgroup of GTAs (e.g., international GTAs, novice GTAs). For example, Hsu (2019) developed an online GTA training module that considered topics surrounding diversity and inclusion in engineering education. Similarly, Verleger and Diefes-Dux (2013) focused on improving feedback by GTAs to students in large undergraduate engineering classes. Targeting international engineering GTAs, Agrawal (2018) highlighted the importance of creating an educational environment that values cultural and linguistic diversity. Although these are important components of teaching and learning – and these should be included in pedagogical PD programs for GTAs – research considering GTA preparation that do this as part of a comprehensive PD program is scarce. Among studies on engineering GTAs, there are also many that describe the current status of GTA training and development and do not attempt interventions. These have included a survey to gauge engineering students' satisfaction with the quality of their GTAs (Boudreau & Anis, 2019) and two studies by Kajfez and Matusovich (2013); Kajfez and Matusovich (2020) that explored the motivation and identity development of engineering GTAs. These studies pointed to the need to support and foster the growth of GTAs as educators more broadly and with attention to their contextual needs.

Across the disciplines however, and especially in STEM higher education, there is an increasingly established body of research that supports content for educator development that supports student-centered, active learning pedagogical

approaches (Stanberry & Payne, 2018). Broadly defined, this type of shift from didactic, lecture-based 'delivery' methods toward consideration of student needs and learning styles has consistently brought about better student outcomes in post-secondary classrooms, including for those underrepresented groups that may traditionally be excluded from STEM disciplines (Theobald et al., 2020).

Activities

Researchers have also considered GTA preparation in terms of the activities that the GTAs experience. Professional development in inquiry-based learning methodologies and an emphasis on practical pedagogical practices have been recommended, instead of a focus on university policy or more instrumental tasks such as planning a first day of instruction or designing a course syllabus (Kurdziel, Turner, Luft, & Roehrig, 2003; Young & Bippus, 2008). Longer-term professional learning experiences, and ones that include allowing classroom observation and asking GTAs to reflect on their classroom experiences, have also been shown to have a positive effect on GTA pedagogical experiences (Gardner & Jones, 2011). As these principles are directed towards diverse learning activities that are inquisitorial and experimental in nature, such as workplace learning tasks and case studies, they are both invaluable and necessary. Workplace learning tasks invite GTAs to try a new approach in their teaching setting (e.g., class or lab) and receive directed feedback, while case studies of effective practice enable GTAs to observe and discuss strong teaching practices. However, it is challenging to find this emphasis in PD programs for GTAs in the literature.

Structure

When it comes to the structure of GTA pedagogical training, the literature suggests several types, each offering unique features and benefits. Workshops (e.g., Boman, 2013), for instance, are typically short, focused sessions that address specific teaching-related topics or skills. They are often conducted as one-off events or series of seminars, which have a limited time frame. Certificate programs (e.g., Chadha, 2015) and training courses (e.g., Lang, Randles, & Jeffery, 2020), on the other hand, are typically longer and more comprehensive than workshops, but they can be problematic because they focus primarily on teaching tips and skills at the expense of examining the underlying reasons for pedagogical change. Modular programs (e.g., O'Neill & McNamara, 2016) stand out as a structure that can be flexible and immersive in approach. In a modular program, GTAs can delve deeply into the topics, gaining a thorough understanding of the subject matter. Moreover, these programs often feature a mix of online and in-person components, making it easier for GTAs to balance all their demands. This flexibility is particularly valuable for GTAs who have diverse schedules or varying levels of prior teaching experience. Within this flexible structure, facilitators of the program (instructional coaches, in our case) may be able to respond to participating GTAs' specific needs and capabilities while promoting effective teaching practices.

There is a clear need to support GTAs' professional learning in engineering education. When content, activities, and structure are considered, a discipline-specific, longer-term, modular approach that considers practical pedagogical strategies and that includes classroom observation and reflection may be able to help GTAs to consider both the "how to" and the "why" of effective teaching. Promotion of active learning and student-centered approaches should be considered, even if GTAs do not have much control over their teaching context, as these fundamental shifts in pedagogical approach have been shown to support the learning of diverse students. Based on these aspects, we developed and implemented a discipline-specific modular pedagogical PD program for engineering GTAs in the context of Situated Learning (SL), and explored their experiences during and after their program participation.

Conceptual Framework

Situated Learning (SL)

Situated Learning Theory (Lave & Wenger, 1991) postulates that learning occurs as a result of socially- and culturally-embedded interactions and relationships (Ebbers, 2015; Vermunt, 2015). We understand situated learning to be "a process of interaction and relationship around a specific domain and which occurs within a social, cultural, and historical context, resulting in spontaneous learning" (Ebbers, 2015, p. 650). Learning takes place where the learners interact with a particular environment in a given context within a given community (Goel, Johnson, Junglas, & Ives, 2010; Smith & Semin, 2004). Novices are engaged in particular contexts where they first engage with small tasks and observation and later with more complex tasks, in order to learn knowledge, skills, tools, and culture related to a particular domain. This domain is framed within a community of practice (CoP) in which novices participating in a process of apprenticeship become more engaged members and the established members also have opportunities to reflect on, share, and reexamine sociocultural practices of the community. Thus, the CoP is a reciprocal learning process in which the individual and the group are redefined continuously through temporal and spatial interactions (Ebbers, 2015). In this sense, a CoP is in continual flux that evolves the enculturation of learners in specific culture and contexts (Altalib, 2002).

Situated learning also emphasizes that learners embody the culture of the community to which they belong (Smith & Semin, 2004); it is a process of becoming. As such, identity involvement is a necessary component of situated learning. Identity involvement refers to a process of becoming and feeling affinity to a particular target community (Lave & Wenger, 1991; Wenger, 2013). Identity, as an understanding or sense of self, is dynamic in that "(re)forming of identity is continually undertaken through experiences and relating with others" (McFeetors, 2014) p. 30). Through participation in a situated learning experience, a member develops an identity in relation to the CoP which is both influenced by and influences the multiple dimensions of themselves (Lemke, 1997). In this way, embedding learning within a context provides a space for meaning-making both in terms of the culture of the community and one's own identity (Brown, Collins, & Duguid, 1989).

GTAs, as novices who are only beginning to develop their sense of belonging to a CoP but are not full-fledged professionals, may find there are tensions among their identities as engineers (or engineering researchers), as students (Johri, Olds, & O'Connor, 2014), as learners, and as teaching assistants who needs to help undergraduate students in engineering classrooms. For most GTAs, educator identity develops by happenstance rather than design since they typically receive little pedagogical support (Shadiow & Weimer, 2015). This means that they usually do not actively shape their educator identity, nor do they pre-plan its formation. Yet, without thinking about what teaching and learning means, they are often asked to be in a position where they instruct undergraduate students. By engaging GTAs in the context of situated learning and CoP interactions, we aimed to understand how GTAs reflect, discuss, and learn about pedagogies in undergraduate engineering education.

Method

We employed a qualitative case study approach, which involves "an in-depth description and analysis of a bounded system" (Merriam & Tisdell, 2016, p. 37), to gain insight into how GTA participants utilized a PD program's features as they engaged in the learning process. Through interpretive inquiry (Smith, 1992), we gathered context-specific information from diverse perspectives, revealing GTAs' learning experiences.

Participants

This pedagogical PD program was conducted at a major research university in western Canada, spanning from January to April 2023. Two cohorts of GTAs from the Department of Electrical and Computer Engineering (ECE) participated, as the Chair of the department supported initial implementation in the department. The program was delivered through the university's online course platform and facilitated by an instructional coach. To select participants for the program, a promotional email was sent to ECE graduate students and some GTAs were nominated by their supervisors and/or the department. Out of the 20 GTAs involved in the program, six individuals (30% of the participants) with varying teaching experiences volunteered to take part in this research, sharing their insights and experiences. All six participants were international students at different stages of their doctoral programs. They primarily worked in laboratories where their roles ranged from being a principal laboratory instructor to answering student questions as a teaching assistant. These are typical roles for the GTAs who participated in the two ECE cohorts. Although all the GTAs who participated in the two cohorts were from one department, there are similarities for the GTA process for all departments in the faculty. Discipline specific knowledge is acquired by GTAs as a result of their prior education, practice as engineers and their current graduate studies.

The Program and Its Implementation

This pedagogical PD program for GTAs was adapted from an original two-year, four term program for engineering professors. The original program (12 modules in Table 1) begins with modules that consider the philosophy of

teaching and learning, including consideration of the nature of learners and nature of learning in post-secondary environments, along with equity, diversity and inclusion considerations. These modules lay the foundation for subsequent modules by inviting participants to consider teaching as learner-centered and promoting equity and inclusion. The second theme encourages participants to consider how to foster active learning opportunities, by empowering students to learn through engaging in classroom discourse and short active components in lectures, while becoming aware of how they learn. By considering course design more broadly, participants progress to consider more active learner-centered course designs, such as problem-based and team-based learning, along with designing assessment practices aligned with learner-centered pedagogy. In the final theme of the program dedicated to the scholarship of teaching and learning, participants are invited to consider their identity formation as an educator and how they might consider their own teaching practices as topics for self-study.

Table 1

Pedagogical PD program for engineering professors and GTAs

Theme	Module
Philosophy of Teaching and Learning	1. Nature of Learners
	2. Nature of Learning
	3. Equity, Diversity, & Inclusion (EDI) for Teaching
Fostering Learning Opportunities	4. Interactive Lectures
	5. Classroom Discourse
	6. Empowering Students to Learn
Designing Course for Learning	7. Problem-based Learning
	8. Team-based Learning
	9. Assessment Practices
Scholarship of Teaching and Learning	10. Forming an Identity as an Educator
	11. Professional Learning Communities (Omitted for GTA program)
	12. Researching Educational Practices in Education (Omitted for GTA program)

This GTA program was facilitated by an instructional coach with over 30 years of experience as an educator. Recognizing that GTAs' tenure in the faculty may be shorter and less predictable than a professor's, it was necessary to tailor the program so that the timeline could be condensed to a single academic term of 10 weeks. To begin, we decided to remove the last two modules (Module 11 and 12) due to their strong focus on faculty members. Then, the instructional coach spent two months prior to implementation modifying the original two-year program module content which was designed for professors to make it more relevant to the GTA experience. Modifications included replacing articles, videos, case studies and activities (including workplace learning tasks) with more relevant substitutes that referenced the roles, workload, and responsibilities of GTAs and laboratory instructors.

Each modified module includes specific objectives, selected readings, video cases, podcasts featuring experts, reflective questions, and opportunities for the GTAs to develop and submit their own products related to the module topics. Examples of these products include designing interactive learning activities for their students and creating learning objectives for their laboratory instructions. For instance, GTAs work with undergraduate students in laboratories, thus, the concept of lesson and teaching was situated in laboratory contexts. Also, a specific peer teaching session was included where participants lead a planned introduction to or First 5-Minutes of a Lab Lesson to their weekly cohort during the Community of Practice (CoP) meeting. By giving GTAs a safe space to practice their pedagogy and receive constructive feedback from the instructional coach and their colleagues, participants would have chance to refine their instruction and interactions with learners before they actually step into the lab classroom. This modification was critical for GTAs who do not have teaching opportunities in classrooms.
The instructional coach visited the GTAs in their teaching environments where possible and used this experience to contextualize the CoP meetings. The GTAs had the opportunity to discuss their questions, observations, and experiences from the modules and their teaching or laboratory practices, relating them to the module topics during the CoP meetings. GTAs spent approximately 4-6 hours per week for three months on this program. Most of this time was dedicated to asynchronous, independent interaction with the online module content and developing their teaching products.

Appreciating the value of the community of practice (synchronous) portion of the program, and the necessity of the instructional coach sharing their experience and expertise during that time, weekly in-person CoP meetings were scheduled for 80 minutes. This allowed participants to experience the types of pedagogical approaches that are active and student-centered described in the program, as it was modeled by the instructional coach. The CoP also included module content-based discussions and responses to the participants' subsequent questions. During several CoPs, participants presented overviews to their peers of how they would implement their ideas into the laboratory/seminar environment or practiced teaching elements including introducing a laboratory lesson and active learning approaches. The CoP was a safe and supportive environment to wrestle with new pedagogical ideas and try new teaching approaches for the first time.

Throughout the program, the instructional coach helped guide and support the reflections and discussions among participants. The instructional coach was not a member of the professional community per se (was not an engineering graduate student or GTA) and thus acted as a facilitator of this process, and included observations of teaching in laboratories and feedback on artifacts produced (e.g., course materials, etc.) that were produced by the participants to inform and guide the CoP. It is important to note that the instructional coach was not involved in evaluating TAs and was not in any position of power with regard to their positions. The instructional coaching was intended to provide support and expertise in pedagogical practices.

Data analysis

The collected data underwent qualitative thematic analysis, using open and axial coding processes following the method suggested by Braun and Clarke (2006) and Williams and Moser (2019). The research team individually reviewed the GTAs' products, transcribed data from the CoP meetings and interviews, and analyzed the data (open coding). Individual researchers completed the open coding to saturation. During their open coding, they highlighted certain data on the interview transcripts and wrote down key words and overall interpretations. Later, the results of the open coding process were shared and discussed at the data analysis session. Diverse aspects and interpretations were shared and written down so that the team could see diverse ideas from each member and visualize how the ideas were connected and could be coded and categorized. When the researchers could see similarities and differences in individual data interpretations from open coding and the connection between their ideas and interpretations, they added these diagrammatically and wrote down reasons for connection. In this process, the team read the data out loud and revisited their independent coding and interpretation. When there were differences in our coding, we discussed where and why the differences emerged and realized differences emerged not because the ideas were different but because data is often rich, including various aspects of participants' experiences. For instance, one paragraph represented a participant's metacognitive practice as a learner as well as her lack of teaching experiences. These differences were revealed and resolved through conversations.

Subsequently, at the next analysis session, the researchers revisited the ideas and the visualization of how ideas were connected and discussed possible themes arising from the analysis (axial coding). As a group, the team synthesized the earlier codes and identified the major themes. For example, quotes like, "I am a TA now, and I don't make any rules for the class... So I cannot see the benefits I gained from here in my work or my TAing" were reflected on the whiteboard as "level of responsibility" and "they don't design the class" during the first meeting. These ideas then shaped the theme of tension between what is being taught in the program and their practices as GTAs.

Findings

Space and opportunity to think about teaching and learning

During the interviews, some of the GTAs reflected on their novice approaches to teaching before the program. One said: "I had some vague ideas about teaching even before I take [sic] this program, but this program helped kind of shape my specific ideas about all these." As exemplified by this quote, the majority of GTAs did not possess a clear understanding or a strategically-designed plan for their teaching before the program, likely due to a lack of opportunities provided to support them. A key element of these opportunities could be seen as space, by which we mean the confluence of setting aside time to think and reflect, to gather with others to discuss, to receive input of information and ideas, and to have this arise at a time that coincides with assigned teaching-related tasks. Thus, the program provided space for the GTAs to thoughtful consider and learn about teaching.

The GTAs mentioned how their teaching methods were often improvised, "At the time I used my intuition and some sort of my experience to teach complicated matters to students. And after attending this course I found out that there is some sort of strategic ways." This observation underscores the notable absence of sufficient space and opportunities for GTAs to engage in thoughtful consideration of pedagogy. In this absence, GTAs found themselves compelled to depend on their "intuition" as a guiding principle for their teaching practices. Some GTAs recounted how they had few previous ideas about how to help students:

> Because before that [the program] everything was like a trial and error, you teach some courses, you get some feedback from the students, … but this course provides this amazing opportunity to learn about everything, without having the pressure of actually teaching anything.

As the GTA who shared the above quote articulated, resorting to "trial and error" and adjusting teaching practices based on student feedback, without adequate pedagogical understanding, may be the only option GTAs were left with to contemplate and develop pedagogical knowledge previously. Nevertheless, this approach does not necessarily support sustained and significant pedagogical development and may not consider the needs of the students who are taught using "trial and error" pedagogies.

After having experienced the program, GTAs commented about how the depth and specificity of the program enabled them to think about teaching and learning. Some mentioned particular areas of the pedagogical curriculum, including Bloom's taxonomy and diversity among learners as useful content for their teaching. One GTA said: "Bloom's Taxonomy for example, was amazing, I was not aware of these taxonomies." Drawing this particular framework into the awareness of the GTAs allowed them to learn how to ask better questions when interacting with students, thus impacting their teaching practices.

Another GTA reflected on his opportunity to learn and was able to identify many of the program elements, or "techniques," related to teaching:

> So overly, [sic] I learned a lot. So, before joining this amazing program, I had some idea about, different people have different learning styles, but through this course I learned a lot. Learned about how many in variation and diversity we have in the learning and teaching experience, I learned a lot of techniques to manage my future classes. For example, how to conduct, how to create this course plan, how to manage each individual session of my lectures, how to plan ahead and lots of other amazing techniques. For example, I think I already mentioned this about two-stage exams, they are also, so yeah, thanks to this program I learned about all of these things.

These statements highlight how the participants started to reflect on what teaching and learning means in their contexts and to them. Some of their understandings were in the early stages of emergence and would require further

consolidation, yet, it was evident that they became more aware and reflective about their actions toward undergraduate students.

Learning approaches to implement student-centered pedagogy

The program included many constructivist pedagogical approaches, such as classroom discourse, problem-based learning, team-based learning, and interactive lectures. Its overarching goal was to guide GTAs in comprehending the significance of placing students at the center of the learning process. As the program concluded, GTAs demonstrated a growing understanding of and appreciation for student-centered pedagogy. They commented: "The most valuable really is for me is empower students to learn", "I think interactive lectures really make the students engage in the learning process, because for engineering labs it's somehow important if the students can actively engage in the material that you are trying to teach them",

> In the future, I focus on the, thinking about how my students think about the concepts and why they are struggling, and how I can just maybe switch some, something, very minor things, and they become more proficient in their understanding.

> Making students active and engaged all the time, that was something that I had no idea before, and I believe that's one of – or if I want to rank all of these strategies that we discussed in this course, active learning is the top important thing in my mind if I want to do some instruction in the future.

By employing key terms such as "empowerment," "engagement," and "interaction," and offering detailed explanations, GTAs emphasized that their intention to embrace student-centered pedagogy is not merely a result of restating course material but a genuine comprehension of the underlying reasons and methodologies. They demonstrated a clear understanding of the rationale and importance of shifting toward student-centered pedagogy. Furthermore, participants explicitly recognized the significance of engaging students through effective approaches proposed in the modules: "The first two modules show how to engage students and how to be a good instructor…My teaching techniques improved a lot ... [with] problem-based learning or project-based learning",

> So, as a TA, I have many things to consider, especially two stage exams…. I will definitely try that as my first teaching experience in the next semester. And the lesson plan was the most powerful thing. It has a blueprint of everything and I probably plan ahead for all of my courses.

GTAs mentioned various tools and techniques that could be effective to help students, such as two-stage exams, to support students' active, collaborative engagement in their learning. Two-stage exams is a process that allows students to collaborate in a second stage after having completed the exam first individually. Notably, this also aligns an assessment practice with using an approach like problem-based learning that is also active and collaborative. One

participant concluded, “that’s actually learning, giving students the opportunity to go back and forth and fix their mistakes… that's the definition of learning [to me],” demonstrating their understanding and incorporation of a student-focused approach. GTAs were shifting their sense of what constitutes learning from students receiving information in lectures toward constructing knowing from their experiences of being active.

Recognizing CoP and the value of learning as a community

Weekly CoP meetings allowed participants to share their perspectives and to collaboratively construct knowledge through discussions. Additionally, they provided an opportunity for participants to reflect on their developing educator identities (Bale & Anderson, 2022). A GTA commented on CoP meetings:

> I was more able to participate more actively in the co-op meetings... It helped me a lot to, like, engage with the other peers and get their opinions, I also shared my opinions and kind of exchanged ideas and learned a lot from that.

As emphasized by the GTA, the interactions within CoPs exhibited a reciprocal dynamic. It was crucial to articulate the evolving understanding of effective pedagogical strategies, with other participants stating, “exchanged ideas and learned a lot from that.” This explanation highlights the strength of CoPs in fostering reciprocity, as a community cannot thrive through a one-way interaction where the instructional coach imparts information to the participants. We believe that sustained change in teaching practices follows from these types of transformative experiences. When the GTA emphasized that they were "able to participate more actively," they began to recognize what constituted an active learning experience, a point also highlighted by some others: “I think the most interesting part is about the general [CoP] meeting … because the structure is very amazing and … the meeting I feel like is really active so I really enjoy it on this part.” It was evident that thinking and talking about “teaching” together with others in similar situations was meaningful and effective for GTAs. In this way, the CoP contributed to the space that GTAs needed to focus their thinking on teaching within the many demands of being graduate students.

GTAs highlighted the significant role the instructional coach played in the CoP meetings as a facilitator and indicated that they observed his educational practices. One of them expressed it as: “He can be a role model for many of us in terms of a teacher.” The importance of observing an experienced teacher who embodied the ideas in the program modules provided coherence across all elements of the program.

Beyond simply recognizing the instructional coach as a role model, GTAs also took the opportunity to identify what pedagogic moves the instructional coach made that demonstrated that he was a master teacher. What this indicates to us is that the GTAs were able to connect the ideas they were reading about in the modules with actions they were observing in an experienced teacher. They mentioned: "The synchronous module [CoP]was amazing. Every time

[the instructional coach] had something to amaze us with, a new teaching style or a new engagement technique and yeah, I really appreciate everything about the synchronous part",

> The [instructional coach], for instance, collaborate[d] with all students. He tried to make eye contact with all the students. That was something that I saw, but I didn't notice it as an important teaching feature that an instructor should have in class. But after having a lecture about … interactive learning … it grabbed my attention more toward these behaviours.

As these comments indicate, the CoP meetings were perceived as an important learning activity that functioned as a collaborative learning environment. At the CoP meetings, GTAs observed, noticed, and appreciated specific examples of the instructional coach's modeling such as making eye contact with individual learners and embedding certain pedagogical strategies in the sessions. The GTAs' awareness and paying attention to these mostly unspoken pedagogical practices during the CoP are valuable aspects of their learning and growth in the program. They could observe and notice how teachers nurture learners and how instructional strategies could be implemented in classroom interactions to engage learners. The community-based interactions were beneficial and crucial for them to reflect on what teaching means and how it can be practiced. This type of benefit through community-based interactions was also highlighted by Harper, Zierden, Wegman, Kajfez, and Kecskemety (2015).

Emergence and challenge of educator identity formation

Throughout the program, we aimed to provide opportunities to GTAs to reflect on their roles as educators or someone who is responsible for helping students with learning. We see this as an emerging process of forming an educator identity. Two participants noted: "Regarding the identity and perception of myself, as I mentioned, it changed a lot", "Definitely my perception as an educator or if you want to call it educator of engineers changed a lot".

While these reflections were quite general, they demonstrate an emerging awareness of themselves as educators – an identity that they can continue to form. These nascent statements are meaningful as educator identity emerges and signified an early understanding, coming before more fundamental changes in their core beliefs and values as educators. We expect that as their sense of themselves as educators becomes consolidated over time that their voices as educators will also grow and result in more articulate expressions of their educator identity.

One GTA provided an example of transferring the acquired knowledge to a different academic activity (e.g., presentations) which could be interpreted as a sign of an emerging educator identity as suggested by Kajfez and Matusovich (2020): "I try to apply all of these features in my own presentations because … the only chance that I have so far is to present something that I know to other people that have no idea about".

We also observed challenges surrounding educator identity formation. With the limited opportunities to design or teach the whole courses, the majority of the participants did not describe themselves as educators fully, but only as teaching assistants who need to follow the instructions given by professors or by prescribed course materials. Some of the GTAs' comments reveal that they did not feel empowered because they could not immediately transfer some of their learning to their practices: "I think all these modules are useful. It's just in the context of TA teaching, I think some of them are not that immediately can be used in the TA context." Another explained:

> Forming an identity as an educator is somehow more valuable for our own future teaching career. … We have two roles here at this university for TAing. One is teacher assistantship and the other is lab instructor. So I don't have many [opportunities] of these as a teacher assistant. Because I am a TA now and I don't make any rules for this class. But for future courses, could be so useful.

We see here that this GTA had a strong sense of his identity as a teaching assistant that was shaped by the role he fulfilled. He also pointed to a distinction between what it meant to be a teaching assistant and lab instructor. These two different identities were echoed by another GTA who explained, "EDI for teaching is kind of the thing that can be applied to all roles in a classroom. Either teacher assistantship, or lab instructors." Interestingly, broader issues that an educator would need to be aware of and enact were seen as transcending these identities. We suggest that perhaps this insight on the part of the GTA could be a promising, nascent shift toward an identity as an educator that is lived out in any classroom context or role where the aim is to lead the learning of students.

The value of the pedagogical PD program being investigated here is that the GTAs became open to the idea that educators have a particular kind of identity and that discussions toward forming an identity as an educator occurred within the CoPs and were prompted by the module content. This provides an intentional opportunity for forming an educator identity that is contrasted with the literature cited earlier (see Shadiow & Weimer, 2015).

Discussions

Given the high number of GTAs and their often overlooked roles in higher education, there is a need to rethink GTAs' roles and responsibilities in university laboratories and classrooms to enhance undergraduate students' learning experiences. This study provides the first evaluation of a program designed to enhance GTAs' understanding of teaching and learning and their instructional practices. The results indicate that supporting the development of GTAs' pedagogical skills can enable them to plan and apply more effective educational practices earlier in their teaching careers. The findings suggest that the program encouraged the GTAs to reflect on teaching and learning in engineering laboratories and classrooms. It was evident that they appreciated learning about tools and approaches that they could implement in their current and future teaching. They appreciated the social context of CoP where they shared their learning and teaching experiences, perspectives, and challenges in teaching. The

conversations and interactions with the instructional coach were seen as significant to help develop the GTAs' engagement in the module contents by encouraging them to cognitively and metacognitively reflect on teaching and learning and forming their identity as educators.

Yet, there were also tensions and challenges in learning through the program. The GTAs found some content was not directly implementable or useful in their current roles, diminishing the intended situatedness of the program. GTAs acknowledged the potential impacts of pedagogical development in their future career, just not necessarily at the present time. In their assisting role, GTAs felt that their authority to make pedagogical decisions in a course is somewhat limited (Barr & Wright, 2019). Researchers (e.g., Bale & Anderson, 2022) explain that how much GTAs see themselves as educators depends on how much their supervisors engage them as educators in the course design and teaching and how these supervisors approach their role in terms of guidance and empowerment. Increasing the number of instructors who are engaged with the Professor development program will likely increase the alignment between what is taught in the GTA program and what the GTA experience in the lab or classroom. In addition, discussions in the CoP could address how GTA could begin to use the skills even if they do not have control of the course. In this study, GTAs felt they had limited power to contribute to pedagogical decisions for students, which constrained their ability to practice their learning. Moreover, this lack of empowerment could undermine their ability to identify themselves as educators (Barr & Wright, 2019). In an alternative scenario, where TAs are given opportunities to plan and implement educational practices, they could receive constructive feedback as well as acknowledgement for their achievements. This, in turn, would support their growth and confidence as educators (Harper et al., 2015). A mutually agreed-upon definition of roles and responsibilities between faculty and GTAs can contribute to the development of their teaching identities (Bale & Anderson, 2022). A recommendation for further cohorts is to share with supervisors of the participating GTAs the goals of the TA pedagogical program and assist in negotiating opportunities for participating TAs to collaborate with their supervisors in making some shared pedagogical decisions.

In this study, many GTAs envisioned their future career as involving teaching, which is a common path for many graduate students (Kajfez & Matusovich, 2013). Since many GTAs aspire to pursue an academic career, it would be proactive to enhance their teaching competencies for their current and future higher education classrooms. Additionally, this can foster a culture within Faculties of Engineering that value and prioritize teaching excellence alongside research by encouraging GTAs, who may become future professors, to view teaching as an essential component of their academic identity and career trajectory.

This study is not without limitations. The study was conducted with GTAs in the Department of Electrical and Computer Engineering with a small group of volunteer participants. The results reported here cannot be generalized to all GTAs' experiences of the PD program. As each discipline has specific types of laboratory work, the GTAs' experiences of teaching and helping students with laboratory work are different from ones in civil, mechanical or

biochemical engineering laboratories. Therefore, we only shared GTAs' roles, tasks, and experiences of teaching related directly to electrical and computer engineering practices, thus limiting the findings and interpretations to this context. As this is the first implementation of this pedagogical PD program, we have used this pilot project to begin to identify the contextual and situated features of GTAs' work to continue modifying and strengthening the PD program. We have already begun several new cohorts of GTAs, drawing on many more engineering disciplines and have created interdisciplinary CoPs. Further program evaluation of these broader groups of engineering GTAs will follow to understand the complexity of their experiences and educator identity formation in higher engineering education. With respect to scaling up the program and expanding it to other departments, this requires engaging with departments and faculty supervisors to understand how GTAs' experiences and interests in pedagogies develop throughout the program and how they can collaborate with GTAs to seamlessly integrate classroom learning with hands-on laboratory work, thus to enhance undergraduate students' learning.

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Corresponding Author Contact Information:

Author name: Mijung Kim

Department: Faculty of Education

University, Country: University of Alberta, Canada

Email: mijung.kim@ualberta.ca

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