A Literature Synthesis of Professional Development Programs Providing Pedagogical Training to STEM Graduate Students

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***Abstract*— This work-in-progress study synthesizes the literature pertaining to programs that aim to develop the pedagogical skills of STEM graduate students pursuing a career in academia. The United States continues to experience a severe lack of STEM professionals needed to be able to stay at the forefront of global technological advancement. Persistence rates in undergraduate STEM programs have shown minimal improvement over the last decade. Research suggests that inadequate teaching is one of the major factors for students leaving STEM fields. In this light, there is an increasing interest to improve and reward contributions to teaching excellence. But conventional systems, particularly at R1 institutions, continue to prioritize research productivity in faculty hiring and tenure/promotion decisions. While new faculty are expected to be teaching-ready, little to no training is provided to graduate students pursuing an academic career. Since 1993, programs such as Preparing Future Faculty (PFF) and the Center for the Integration of Research, Teaching, and Learning (CIRTL) have been actively trying to fill this gap in training future faculty for teaching. A comprehensive assessment of current practices in pedagogical training provided to graduate students can inform future changes in policy and practice. This study is the first step of a larger study and aims to synthesize and summarize the current state of programs in universities across the United States that focus on such pedagogical training. Initiatives focused on professional development of graduate students in STEM fields, with special attention to engineering, were screened for programs specifically contributing to pedagogical development. Published articles in the *Journal of Engineering Education*, *Conference proceedings of the American Society for Engineering Education*, and several databases available through the University of Cincinnati library Summon search engine were used to find relevant publications on program implementations and evaluations over the last two decades. Qualifying papers were summarized and compared to construct a description of the past and current state of pedagogical training received by graduate students in STEM majors. The ultimate goal of the larger study will be a list of identified promising practices that show evidence of effectiveness in preparing graduate students for teaching and a set of recommendations for redesigning or implementing such programs in engineering.**

Keywords—preparing future faculty, graduate student, teaching assistant, professional development, pedagogical training

I. INTRODUCTION

In 2012, The President's Council of Advisors on Science and Technology warned the United States of the need of 1 million more STEM professionals than the projected number by 2022 [1]. However, the undergraduate persistence rate in engineering rapidly declines from 82% in the second year of college to 33% in the fourth year, and these numbers have shown minimal improvement over the last decade [2].

Pertaining to these declining persistence rates over the four years of most undergraduate degrees, Marra, Rodgers, Shen & Bogue [3] attributed one of the factors for students switching from STEM fields to other majors as poor teaching and advising. This was concurred by Geisinger and Raman [4] who reviewed the results of 13 other studies, each showing evidence of inadequate teaching and advising as a reason for student attrition in engineering majors. These claims remain consistent since they were first made in 1997 in Seymour and Hewitt's seminal work, *Talking about Leaving: Why Undergraduates Leave the Sciences* [5]. More recent research suggests that teaching quality and low teaching self-efficacy among college instructors, even at the teaching assistant level, can have a deep impact on undergraduate learning and attrition, say Wright et al. [6].

One of the challenges with addressing this issue is that quality of teaching continues to remain a low priority for universities with very high research activities (e.g., R1 institutions). Data collected for *Science and Engineering Indicators 2018* indicated that R1 institutions in the US enroll about 2.1 million students in undergraduate degrees annually [7]. Training future STEM professionals at all levels of education is critical at such universities because of their high enrollment coupled with low retention rates [8]. However, undergraduate education has been continually neglected since postwar times because faculty members are rewarded primarily for their research output, numbers of Ph.D. graduates mentored, and the procurement of external research support, rather than for contributions to undergraduate education [9, 10]. Lack of attention to quality in teaching creates an environment non-conducive to student learning [11].

Several researchers have studied how faculty in higher education get trained [12, 10]. Socialization [13] to an academic career happens during graduate school, commonly in a doctoral program [14]. It has been observed that new faculty at R1

universities are often not prepared to balance the demands of a position that includes teaching, mentorship, grant writing, and administrative obligations [15, 16, 12]. It has been observed that recent doctoral graduates face a lot of difficulties in their teaching responsibilities for several reasons. When hired, they are expected to teach in a broad undergraduate curriculum although they have spent their recent years focusing on research in a narrow niche within one discipline [15]. Moreover, the only teaching opportunities they experience are through the few teaching assistantship positions that may have been available. Even then, many of these experiences limit the graduate student's duties to grading or supervising students in laboratory activities without any in-class teaching experience. Even so, Austin et al. [16] cite research detailing institutional need as the only basis of availability of such teaching assignments rather than as a salient part of the professional development of a graduate student. Their research suggests that teaching positions are typically regarded as less prestigious by STEM doctoral students when compared to research engagement. This further leaves them unprepared for the teaching commitment expected of them.

Research has been conducted to address this concern of the lack of preparation for teaching responsibilities among graduate students interested in pursuing a career in the academy. A Council of Graduate Schools (CGS) was formed for Deans to share policies and programs. The National Science Foundation (NSF) also supported the Center for the Integration of Research, Teaching, and Learning (CIRTL) as part of a national initiative that continues to serve as a high-impact professional development program for STEM graduate students and postdoctoral researchers. In 1993, the Association of American Colleges and Universities (AACU) laid down the foundation for the Preparing Future Faculty (PFF) programs towards eliminating gaps in career development of graduate students [16, 11, 17]. Over the next decade, 76 grants were awarded to 44 graduate institutions, and 339 colleges and universities participated in PFF "clusters" to help graduate students learn about and participate in faculty roles at nearby institutions through seminars, mentoring, workshops, and observation [14, 18].

Despite the recognition of the importance of professional development for STEM graduate students, little work has been done to understand the scope of programs available or what practices best serve to prepare STEM graduates for future careers in the academy. This paper attempts to elaborate upon the recent programs that involved graduate students' training in teaching practices in order to inform future initiatives. Similar work done in this area is elaborated on in the following section. After elaborating on the methods of conducting the literature search, findings are categorized into two sections: studies that elaborate on the current needs of graduate students and the different models used across institutions to serve this purpose. The paper concludes with discussing the implications of the findings and scope of future work.

II. Background

As mentioned before, articles presenting a review of programs focusing on pedagogical training for graduate studentes were very limited. Diggs et al [18] reviewed several PFF initiatives and found that enough data was not being collected to report on the effective strategies in development of future faculty. Other studies like [19] have also reviewed other graduate student professional development programs before 2015 and then elaborated on the interventions in their institution. Rose in conjunction with Social Sciences and Humanities Research Council of Canada published an all-encompassing review of professional development for graduate students in Canada [20] but does not focus specifically on students pursuing an academic career and less so on pedagogical skills. In 2011, Gardner and Jones [21] conducted a review of training programs for Graduate Teaching Assistants (GTAs) in science but did not include programs that were open to other graduate students as well. In addition to this, two other studies [22], [23] conducted systematic reviews of programs for faculty developments but did not focus on graduate students. As is clear, work citing an overview of recent programs implemented for STEM graduate student training in pedagogy was not found.

III. Methods

Since the focus of this study was to further the pedagogical practices in engineering, the authors first surveyed the *Journal of Engineering Education (*JEE) with the keywords "preparing future faculty" in the title for recent articles (2015 and beyond). Surprisingly, this yielded no relevant results. The authors then conducted a similar search in the ASEE conference proceedings. This search was then broadened to include the keywords anywhere in the papers and that yielded a few relevant results although not specific to PFF programs. Papers that focused on aspects of preparing future faculty other than preparation for teaching, such as mentorship and grant writing were excluded from this review. Following this, the authors scouted for articles on the Summon search engine of the University of Cincinnati library. This search engine has access to research databases like ERIC, Academic Search Complete, ProQuest Research Library, ProQuest Dissertations and Theses Global, to name a few. The search engine also has the option to view articles beyond the collections of the library. The authors believed this would yield a comprehensive list of relevant articles. Because the search was confined to articles primarily published after 2015, results in engineering were limited and so the search was broadened to include all disciplines. It was expected that large scale programs or initiatives in other disciplines could inform practices in engineering. References of the articles reviewed were also examined to identify additional relevant articles. As was mentioned earlier, the primary source of teaching experience for graduate students is in the role of a Graduate Teaching Assistant (GTA). Therefore, articles reviewed included initiatives both pertaining to GTA training specifically or encompassing resources available for all graduate students. It should be noted that only programs implemented within the U.S. were included in this work.

IV. SYNTHESIS

A. Benefits and gaps in graduate professional development

Heflinger and Doykos [24] conducted a study at a large, private, R1 institution to evaluate the extent of professional development and career socialization in doctoral programs by understanding the perceptions of doctoral students towards resources made available to them across disciplines. Only 63% of students perceived that they received access to adequate professional development in teaching as opposed to 98% who said their doctoral program prepares them to be experts in their field and 92% who could keep up with the latest research techniques. Specific to engineering, these numbers were 68.1%, 96.9% and 93.3% respectively. While, it is less disheartening to see these numbers over 50% when compared to a mere 44% of all respondents feeling prepared to run a research group, it is evidence of the lack of teaching development initiatives at R1 institutions. This is particularly significant since Connolly, Lee and Savoy found that there is a positive relationship between teaching development participation and participants' college teaching self-efficacy [25]. Similarly, Wurgler et al found that graduates of a PFF program at their university felt more competent in their first jobs than graduates who did not participate in the program [26]. When a training and orientation program in inclusive teaching was conducted at the University of Michigan for their engineering teaching assistants [27], both undergraduates and graduate students agreed that they found teaching experiences rewarding and felt easier to connect with their students. The undergraduate student instructors even said that it helped them reinforce their own content learning. Research also suggests that undergraduates find mentorship from graduate students more effective than from faculty because they find common ground to form close relationships more easily [19]. This is evidence that training programs in teaching and mentoring can be beneficial to both the graduate student trainees and their undergraduate students. It also brings to light that more initiatives are needed to enable effective relationships between graduate student instructors and students.

B. Recent initiatives

In our preliminary literature review, published research on programs specifically affiliated with the PFF agency were limited. The initiatives discussed in this section did not call themselves PFF, but "prepared future faculty" in some fashion, nonetheless.

One of the programs that had the closest association with training future faculty was founded at Virginia Tech's Department of Engineering Education and partnered with Rose-Hulman Institute of Technology. The Rising Engineering Education Faculty Experience (REEFE) [28] is an apprenticeship model that allowed institutions to host engineering education doctoral candidates as visiting faculty who gained access to services available to a faculty (e.g., committee meetings, ability to work independently on projects and networking events). The host institution, in turn, benefitted from the research expertise of the students to engage in evidence-based practice. While the program was envisioned to help students work side-by-side with experienced engineering education professionals and see theoretical education put to practice, the experience transitioned from teaching-focused to a "needs or best-fit" model. Students were positioned with either the institutional research centers or the centers for teaching and learning of the host, where they collaborated on educational research put to practice. Both graduate students and host institutions benefited from this collaboration with the former getting more exposure to the dynamics of institutions beyond their own. This initiative seems very promising and could potentially serve as a model for structuring future programs in graduate student apprenticeship.

The University of Michigan's Center for Research on Learning and Teaching in Engineering (CRLT-Engin) hosted separate teaching orientations for 90-140 new undergraduate instructors and 100-150 new graduate student instructors [27] with a focus on inclusive teaching. A single-day orientation included multiple sessions of role-play, interactive sessions, group discussions and practicing discussions. Data gathered from focus groups of attendees assisted in identifying needs of student instructors and served as a pilot to improve future practice in student instructors' training.

As a model of University-wide programs, the Experiencing Transformative Education through Applied Learning (ETEAL) at the University of North Carolina, Wilmington organized orientations to complement TA training initiatives within its departments [19]. 48 voluntary participants attended a 4-hour long seminar on enhancing knowledge of best practices in applied learning and increasing psychological well-being of the instructors. In the same research, Parker et al [19] discussed several other university wide programs. The Eberly Center for Teaching Excellence at the Carnegie Mellon University founded a semester long future faculty program which included workshops, seminars and provided teaching feedback through classroom observation and one-on-one meetings. About 6918 graduate students were reported to have benefitted. The University of Tennessee, Knoxville organized workshops throughout the semester for 5982 GTAs, setup discussion groups with faculty members and provided feedback through the observation of teaching. An "Outstanding Teaching Award" was also organized. In an innovative model, Vanderbilt University initiated a graduate teaching fellows' program where veteran GTAs mentored early-stage TAs in addition to all day TA orientations and workshops.

Parker et al [19] also discussed a smaller program at the Department of Chemistry at the University of Maryland which was organized to help new GTAs transition as junior faculty. A six-week course was structured around weekly discussions of problems faced by TAs and a new topic introduction. It was observed that the course evaluations of Graduate TAs by undergraduate students improved for TAs enrolled in the program [29]. Wurgler et al elaborated on the Preparing Future Faculty model at the Sociology department of Indiana University. Graduate students were given access to

faculty shadowing and professionalization workshops. In line with Vanderbilt's model, an advanced graduate student would be enrolled in a fellowship program to mentor first-time instructors and plan a campus wide PFF conference. They also got a certificate in college pedagogy. Program participants reported better preparedness for their first jobs and higher levels of competence when compared to their non-participating peers, albeit a negative relationship between job satisfaction was observed. Wurgler et al. intended to explore the cause of this negative relationship in future work. However, it can be argued that experiences in a preparing future faculty program change expectations from the first academic job of participants and may lead to lesser job satisfaction. Peers who have not been exposed to such experiences during their doctoral programs may have lower expectations. Future work is needed to confirm this argument.

V. Discussion and Future work

The abovementioned initiatives provide a diverse background of some of the recent efforts in increasing pedagogical training of graduate students to help prepare them better as future faculty and improve STEM retention. While some programs were not specific to STEM or engineering, training models provide for a structure that can be inculcated in the engineering discipline. While this work is just a first step of a larger study in progress and is certainly not exhaustive, it does bring to light certain trends in current state of scholarship in professional development of graduate students. In particular, programs for engineering were very few. Moreover, interdisciplinary programs or intra-disciplinary programs focusing on improving pedagogical training are also limited. For example, in their synthesis of all PFF programs until 2017, Diggs et al noted only 3 programs that involved teaching practicum: University of Maryland, University of Cincinnati – Department of Electrical Engineering and Computer Sciences, and Rensselaer Polytechnic Institute [18]. Their synthesis concluded that there was a dearth of reporting on programs and the lack of data provided a substantial barrier to fulfilling their research goals. Most published research described the implementation of such programs with very little reporting on the outcomes and effectiveness. This is even more surprising because the United States is also the only graduate school system with several large databases (e.g., the National Research Council (NRC), Assessment of Research-Doctorate Programs and the Survey of Earned Doctorates), that can serve as sources for comparisons across institutions. However, there are significant gaps in instruments than can assess the factors that influence student outcomes and more standardized data collection and reporting at the national level can help in filling this gap [30].

We acknowledge that collecting data on large or small scale does not come without challenges. To begin with, given the nature of doctoral programs, it is often unclear what data is relevant. For instance, what skillsets should be focused on given the career tracks of graduate students are so diverse? Even the standards of success of graduate programs to be gauged are unclear. This makes gaining knowledge on doctoral experience hard to navigate. Even so, in progressing the development of such programs, it is often debated who should be primarily responsible – the individual faculty mentor of a graduate student, the department or the university. Regardless, it has been well established that graduate students do not feel prepared for the responsibilities of a career as a member of the faculty in undergraduate education [31].

Again, this paper only serves to lay the foundation for a more in-depth investigation in this area. Future work will focus on filling gaps in the knowledge of effective practices. Work will continue on the literature synthesis of programs that identify as PFF programs. Additional programs will be surveyed by adding more keywords and expanding search on different search engines. In addition to using scholarly articles, marketing material of active programs like websites, brochures and email broadcast will be gathered. Currently, the authors are developing a survey for distribution to various colleges of engineering across the United States with the goal of understanding the current state of programs available to graduate students for their professional development. Follow-up communication to program managers, department heads, and TA training managers has a lot of potential to provide specific details of these initiatives and their innovative practices which are not available through published articles solely. These methods will advance the current work in synthesizing effective practices that can inform policy and change in graduate student professional development for a better-prepared future faculty.

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