# Making Teachers from Students: How Learning Environments May Foster an Interest in Teaching

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***Abstract*—This paper presents an exploratory case study of the interest and participation in teaching, teaching related activities, and research on education among students and alumni at Celadon College, a small engineering school focused on education reform. Prompted by a lack of qualified STEM educators in the United States, this study investigates how to increase interest in education as a career path among STEM undergraduates. A mixed methods analysis of survey responses from 231 students and alumni reveals that, compared to the national average among engineering graduates, subjects at Celadon College are more than twice as likely to indicate interest in becoming K-12 teachers. Analysis indicates that two major factors influence students' position towards teaching and the desire to teach: the development of *pedagogical awareness* and participation in *informal peer teaching*. Our analysis suggests a link between institutional academic and non-academic cultures and students' interest in K-12 teaching. We conclude by sharing a set of questions for further investigation and discussion with engineering education community.**

***Keywords*—Recruitment of STEM Teachers, Academic Culture, Informal Peer Teaching, Pedagogical Awareness, Teacher Motivation***

## I. Introduction

"The United States' position in the global economy is declining, in part because U.S. workers lack fundamental knowledge in [Science, Technology, Engineering, and Mathematics (STEM)] fields," reports *A Framework for K-12 Science Education*, one of the many recent documents that call for improvements in K-12 STEM education [1]. In December 2010, the U.S. Department of Education released the results of the Programme for International Student Assessment (PISA), which compares the performance of 15-year-old U.S. students to their counterparts in other countries. The study reports that the United States is either at or below the test average in both mathematics and science fields [2]. Further, the report issued by the President's Council of Advisors on Science and Technology, *Prepare and Inspire,* demonstrates that whereas one-third of all U.S. college graduates are awarded STEM bachelor's degrees, up to 63% of graduates in China and Japan are earning STEM degrees [3]. The deficient math and science performance of U.S. high school students, coupled with the subsequent lack of STEM college majors in the United States, hinders the country's ability to supply innovators to a growing technological market [4].

One key factor, often linked to the poor performance of U.S. high school students in STEM, is the shortage of well qualified K-12 teachers [5]-[7]. *The Next Generation Science Standards* and many state education standards are pushing for more science and engineering to be included in K-12 education, yet there are not enough qualified STEM teachers to supply even the current curricula [1]. A number of studies investigate out-of-field K-12 STEM teaching, teacher qualifications and the limits of teacher policy, as well as propose potential remedies [6]-[10]. For example, the National Taskforce on Teacher Education in Physics has produced a report indicating that fewer than half of the K-12 teachers of physics and chemistry in the United States hold a degree in their disciplinary fields [6]. The White House has called for 100,000 new STEM teachers to be recruited in the next decade [11]; yet there is little guidance on how to recruit this number of students into STEM education [12].

In order to address the STEM teacher shortage, we must first understand how STEM students become interested in teaching in the first place. A number of studies have been performed with the population of in-training and in-service teachers, which investigate participants' "retrospective" motivations for entering the profession [13]-[18]. However, there are very few studies that investigate the activities or experiences that may be influencing the development of these motivations in the first place and none which specifically address the question of how college students become interested in K-12 STEM education [10].

## II. Celadon College

To address this gap in our knowledge, this paper presents an exploratory case study performed at a small engineering college, which for the purposes of this study we will refer to as Celadon College. Despite offering only engineering degrees and having no formal teacher training certificate or program, Celadon's students have shown considerable interest in education-related careers, resulting in an unexpected percentage of Celadon alumni participating in teaching activities within STEM fields. For example, over 10% of the Celadon Class of 2007 has held positions that involve teaching in a central role [19]. This number does not include those graduates who mentor and volunteer for such activities as

FIRST Robotics, Society of Women Engineers, and other short-term teaching opportunities.

Celadon's mission is to educate innovative and entrepreneurial engineers, and a key facet of the culture is to develop and implement the most effective pedagogical and curricular practices, particularly within engineering education. An intrinsic part of the Celadon's culture, therefore, is the inclusion of students in the dialogue regarding curricular and pedagogical changes at every level [20]. As a part of the "Celadon experience," in addition to receiving a technical engineering education, students are expected to become active participants in the design of their own learning experiences. As classes and curricula are being developed and re-conceptualized, students serve on curricular committees, participate in curricular and pedagogical experiments, assist in co-creating a culture of continuous feedback and improvement, function as teaching assistants, design and implement student-run courses, and actively participate in engineering education research [21].

Many courses at Celadon utilize a project-based learning environment. This student-centered pedagogical practice supports the development of student autonomy through a set of carefully scaffolded, self-directed experiences. A cornerstone of life-long learning competency development, these self-directed experiences have been reported to increase the development of intrinsic motivation by allowing students to guide their own learning and develop interdisciplinary connections between courses [22]-[27]. Intrinsic to development as a life-long learner is a set of skills, behaviors, and attitudes related to critical reflection. It is in this spirit that Celadon students are often invited or required to reflect upon their learning experiences and outcomes. Interestingly, this same reflective practice has been also found to encourage teacher development [28].

Furthermore, the Celadon curriculum includes a large number of courses and activities across all years in which student teaching serves as a mechanism for learning. Team-based projects and collaborative learning are emphasized, which allows most students to take on the role of an informal teacher of their peers. More formally, in the very first semester, Celadon students work with elementary school students as clients for their engineering design projects. A first-year *Electricity and Magnetism* course was run with an explicit pedagogical focus, where students learned the course material through creating lessons and demonstrations targeted at middle school classroom use. Student course assistants (known colloquially as NINJAs) have been a part of the school culture since its very inception, and students are encouraged to take on this role as early as their sophomore year. To provide a more formal setting to those interested in teaching and based on student requests, a new course on *Teaching and Learning in Undergraduate Science and Engineering* was developed and is now a permanent fixture in the College's catalog. Lastly, about 10% of Celadon students are directly involved with formal and informal outreach efforts in K-12 settings. A student-run group, Engineering Discovery (eDisco), helps to mobilize student participants, who design and implement curricula either independently or alongside K-12 teachers.

Motivated by the national lack of highly qualified K-12 STEM teachers, this study of Celadon College's students, alumni and culture provides an opportunity to investigate the development and recruitment of future K-12 educators. With this in mind this study poses the following research question: *What factors in Celadon's curriculum, culture, and community may influence the development of interest among STEM students and alumni in teaching (e.g., classroom teaching, mentoring, coaching, tutoring, etc.), teaching-related activities (e.g., curriculum design), or research in education?* This paper discusses implications of the study findings, poses important questions, and serves as a launching point for a conversation within the engineering education community about the ways in which we can support development of future K-12 STEM teachers.

## III. METHODS

### *A. Study Design*

The study uses a descriptive mixed-methods design. The instrument used for the study is a survey implementing a concurrent transformative design model with quantitative and qualitative data given the same priority [29],[30]. Data collected include demographic information (major, year of study or graduation, gender, current position, involvement in teaching activities) as well as answers to multiple choice and open-ended survey questions. In the design, we also considered literature about the Factors Influencing Teaching Choice (FIT-choice) scale [31].

### *B. Instrument and Data Collection*

The 7-item, web-based survey instrument investigated each subject's significant influences in education, participation in teaching-related activities, motivations for participation, as well as confidence and interest in teaching and education research. In addition to collecting quantitative data by asking these questions in a multiple-choice, multiple-answer matrix format, we also prompted each subject to write explanatory statements illustrating how and when these influences affected them. Finally, we invited participants to add any comments they felt were appropriate.

The survey was emailed to all Celadon College students enrolled in the Spring 2013 semester and all alumni who graduated between 2006 and 2012 — 45% women, 55% men of whom 60% were alumni, and 40% undergraduates. A sample consisting of 231 people responded to the survey in three weeks, giving us data from nearly 28% of the total population invited. The sample appears representative of the entire Celadon student and alumni population, consisting of 45% women, 55% men; 66% alumni, and 34% undergraduates. After data collection was complete and prior to analysis, subjects' responses were pseudonymized using gendered aliases.

### C. Data Analysis

The quantitative and qualitative data analyses were performed concurrently. Descriptive statistics for all quantitative data were calculated and open-coding strategies with the use of grounded theory were employed for qualitative analysis. The integration and triangulation of qualitative and quantitative data were performed at all stages of data collection, analysis and interpretation [32].

The quantitative analysis was performed by investigating each variable through creating visualizations and interpreting trends. Significance was initially assessed by using $\sqrt{N}$ error where N is the number of respondents for the question. Correlations were also calculated for some variables. In the case that an overlap of error bars or a lack of overlap was deemed interesting, either a *t*-test or Wilxocon rank sum test was applied to determine the statistical significance of the result.

The qualitative analysis was performed using the Atlas.ti software package. Starting with "open" coding strategies, the data were split into individually coded segments that allowed for identification of emerging categories [33]-[36]. The process of initial coding yielded 119 codes that, with further analysis, were reduced to 29 core categories. Further rounds of coding resulted in identification of emergent themes that served as a beginning of an emergent theoretical framework [33]-[36].

Occasionally, a mixed methods approach was adopted wherein a group of respondents was selected based on a common category. This group was then compared quantitatively against the remaining survey respondents to determine any statistical difference in their behavior [37],[38].

## IV. RESULTS AND DISCUSSION

Our data indicate that Celadon students and alumni are highly involved in teaching, teaching-related activities, and education research, with 99% indicating participation or interest in one or more activities across these three domains. Specifically, 99% indicated a teaching activity (e.g., serving as a course assistant), 81% a teaching-related activity (e.g., taking a teaching and learning course), and 30% conducting research on education. Eighty-three percent were active across two or more domains, with 28% of subjects active across all three.

When compared to a national survey of engineering students, our results suggest heightened interest in teaching among Celadon students. A study produced by the National Center for Education Statistics (NCES) indicates that a national average of 8% of engineering graduates have taught, prepared to teach, or considered teaching at the K-12 level [39]. Using a similar question, we find that 19% of Celadon respondents indicate employment as a K-12 teacher or future interest in K-12 teaching, more than double the national average.

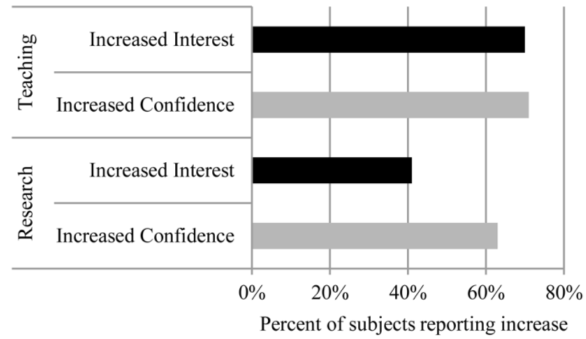


FIGURE I
INCREASES IN INTEREST AND CONFIDENCE

To determine the extent to which Celadon plays a role in the development of interest and confidence in teaching, the survey included a question exploring the effect of the subjects' experiences at Celadon on their confidence and interest in both teaching and education research. Figure I demonstrates that a large percentage of study participants indicate an increased interest in teaching and/or education research during their time at Celadon. Even without comparative data, this suggests that there may be a positive relationship between the Celadon environment and both interest and confidence in teaching. Comparing the change in teaching confidence at Celadon among those who have taught/plan to teach and those who have not taught/do not plan to teach, the results fell just short of establishing a significant difference (W=3495.5, p=0.077).

To understand the underlying reasons for these trends, qualitative data analysis was employed and two emergent themes were identified: *pedagogical awareness* and *informal peer teaching*. Both themes appear deeply embedded in most subjects' narratives, indicating that they are key aspects of the Celadon experience. In what follows, each theme will be described separately.

### A. Pedagogical Awareness

The first emergent theme reveals that development of students' pedagogical awareness (PA) may fundamentally change how they think about and position themselves towards teaching, teaching-related activities, and research on education. The definition of pedagogical awareness, emerging from our data, is any level of recognition of and reflection about pedagogical techniques, curricular structures, learning environment, or educational theory. Additionally, the PA construct in this study incorporates awareness of the importance of high quality education at a national level, including discussion of policy reforms, as described by students and alumni themselves.

Described by 135 study participants, representing 65% of the respondents, the discourse about PA appears in two different modes that may occur separately or concurrently. First, study participants discuss increasing PA while at Celadon; second, respondents illustrate application of their PA while teaching, mentoring, or guiding others. The quotes included herein are representative of the data set.

*1) Discourse about increasing pedagogical awareness while at Celadon.*

While some of the discussions about PA referred to participants' experiences outside of Celadon, 77% of the references to increased PA were specific to the Celadon experience. Study participants often describe specific episodes when they gained exposure to or understanding of an aspect of educational theory. It is during these moments that survey respondents reported becoming more open to and comfortable with the idea of teaching or education research.

For example, Michael describes such a moment in the following way,

> *the MatSci professor['s]… class was project-based, and he was very interested in educational research. This was perhaps my first exposure to many of the concepts which now seem so basic in thinking about how I learn.*
>
> \- Michael, Celadon student

After exposure to new ideas about teaching from his professor, Michael developed intuition which now assists him in thinking about his own learning. Now, he not only thinks differently about education, but ideas which before were not present have become a fundamental part of his thought processes.

Another subject clearly describes the effect that exposure to new pedagogical ideas has on him,

> *My best friend in school … has taught me a lot about teaching. The lessons he taught me completely changed how I approach teaching other people … Lastly, Celadon opened my eyes to non-traditional education. The most important thing I've learned from these experiences is that everyone learns differently and to reach students you need to adapt to THEIR needs.*
>
> \- Jasper, Celadon student

Jasper's conversations about education with his friend and his experience at Celadon open a door for reflective thinking about the ways in which he needs to approach his own teaching practices. For Jasper, teaching now is about "reaching students," employing "non-traditional educational practices," and "adapting to students' needs." Not only is Jasper able articulate his pedagogical awareness, he also seems to interpret specific aspects of classroom practices that may benefit his own students.

Maria adds another perspective when she shares her experiences,

> *I think my experience at Celadon helped me see that education is everyone's job and that we should all be thinking about how it is done and whether we are using the appropriate methods to teach at various levels/environments. I think Celadon instilled in me the belief that we can all have an impact on education, even if we are not personally involved in teaching/ research.*
>
> \- Maria, Celadon alumna

It is clear that Maria's meta-cognitive discourse about education is a result of her Celadon experience. She seems to have reinterpreted what education means for her and has determined her own positioning vis-à-vis education as well as her own role in educating others. From being able to notice and articulate her own educational experiences, Maria moves on to explain that education is a societal responsibility with every single one of us having "an impact" even without "personal involvement in teaching."

*2) Discourse about application of pedagogical awareness*

A number of survey respondents' discourse focuses specifically on the ways they translate their pedagogical awareness into teaching practices. This indicates that in addition to noticing, articulating, and interpreting somebody else's actions in a classroom, these participants are also able to do so in their own teaching. These actions appear to lead to further development of interest in teaching. For example, Aaron reflects on one challenge of working in a classroom,

> *…the challenge is being able to figure out what allows [students] to most easily understand the concept…this has allowed me to discover the exciting part of teaching.*
>
> \- Aaron, Celadon student

Aaron discovers that "the exciting part of teaching" is a pedagogical challenge of deciphering the most effective ways of helping people learn. Finding a greater enjoyment of teaching as well as perceiving improved teaching skills through increased PA was common among many subjects.

According to Greg, being a course assistant *"helped [him] to understand some of [his] strengths and weaknesses as a teacher as well as analyze different teaching practices"* (Greg, Celadon student). For Greg, teaching allowed for moments of self-evaluation and reflection resulting in greater PA and improved "teaching practices."

A number of study participants reported desire to use their PA for the greater good on a national and/or international scale. Motivated by her experiences at Celadon, Eliza, a recent Celadon graduate, examines the ways her newly acquired PA may be used in a context of national education,

> *It motivates me to spend some time thinking of ways that Celadon has taught me engineering and how I could apply [my knowledge] to the Indian education system.*
>
> \- Eliza, Celadon alumna

Likewise, Steph, another recent Celadon alumna, feels that the knowledge gained from a specific course and Celadon overall is something she could use for public policy changes, *I wanted to take what I had learned, both in the course and Celadon as a whole, and find a way to make change, possibly at the public policy level.*

- Steph, Celadon alumna

It appears that the PA gained/increased while at Celadon serves to empower students and alumni to take their knowledge and skills beyond what is known and familiar. As in the quotes above, many study participants indicate increased levels of self-efficacy and confidence in using their PA in practice, be that a context of one-on-one teaching, a classroom of third graders, or a policy making.

What are the specific aspects of the Celadon milieu that serve to develop and enhance students' PA? As per the College's aspirations, Celadon is intentional about involving its students in the co-design and development of an overall curriculum and its individual parts, be that courses, extra- or co-curricular activities, or conversations about engineering education at large. As Oliver puts it, being at Celadon, *"felt like it was a 4-year conversation on education"* (Oliver, Celadon alumnus).

It is also apparent that the project-based curricular and pedagogical structure embedded into the Celadon's academic and non-academic "way of thinking" leads many students to develop meta-cognitively in a way that allows for smooth transference of knowledge and skills. In other words, highly self-reflective by its very nature, Celadon's project-based learning environment allows, unintentionally, for student development along an axis of PA development. This often goes beyond just recognition of one's learning environment and one's positioning vis-à-vis his/her learning environment. We argue here that Celadon's environment also permits development of skills, attitudes, and behaviors relevant to PA, which includes increased self-efficacy and motivations for educational change beyond Celadon's walls,

*It's not any one particular experience, but just having a lot of experiences and talking to a lot of people all around me almost all the time at Celadon. That got me thinking about it, and now I carry those thoughts with me elsewhere, and can spread it to others who don't have such a community.*

- Timothy, Celadon student

Moreover, this culture of educational change while at Celadon seems to create a sense of identity or belonging to something that is larger than students themselves.

*B. Informal Peer Teaching*

The second emergent theme relates the act of informal peer teaching (IPT) to students' desire to teach in the future. Within the context of Celadon, informal peer teachers help their peers with learning on team-based projects or collaborative assignments. Interestingly at the College, even NINJAs (teaching assistants) in their formal and paid position, often take on the roles of informal peer teachers, since it happens that the NINJAs and their peers may be friends and the teacher-learner roles may easily be reversed in a different context. Ninety percent of subjects reported "helping others with coursework" as an activity they engaged in while at Celadon, while 59% reported serving as a NINJA. Of those who have become or are considering becoming teachers in the future, 99% reported helping others with coursework at some point in their education. The evidence suggests that there may be some relationship between participation in IPT and increased confidence in teaching ability. While this finding does not rise to the level of statistical significance quantitatively ($W=3495.5$, $p=0.077$[1]), qualitative analysis demonstrates its importance.

Our data indicate that the culture of informal peer teaching, which is seamlessly embedded into collaborative aspects of Celadon's project-based learning environment, provides students with access to multiple teaching opportunities. These experiences, in turn, may result in Celadon's students and alumni being more likely to teach again in the future. Here is how a Celadon alumnus describes this process,

*From high school into my time at Celadon and into grad school, I frequently took part in unofficial group study activities and, particularly in high school, assisted others with their studies. While these activities were often necessary for my own understanding and learning, I found that my knowledge was very useful for others and has prompted me ever since to offer instruction and help whenever it is requested of me or a need is apparent (this includes my current work).*

- Nick, Celadon alumnus

Nick's IPT experiences stem from the need to work with others to improve his own "understanding and learning." However, another unexpected outcome of doing so for Nick is a realization that his own knowledge may be "useful for others," i.e., increased PA, and the ensuing motivation to teach and assist others whether or not he is called to aid.

As mentioned previously, Celadon's academic culture, by design, puts heavy emphasis on collaborative work. The rationale for this is at least two-fold: the collaborative learning environment is true to the professional practice of engineering and valuable in developing effective communication and teamwork skills, which are also a part of engineering careers. It seems as though, at least at Celadon, the collaborative learning environment allows for more than just an effective way of studying; it is also a way to gain experience as an informal peer teacher with a concomitant increase in PA, incorporation of PA into teaching practices, and a desire to continue doing so in the future. For example, here is how one study participant described Celadon's collaborative environment,

*The community at Celadon remains the only place that I have ever been where the passion for learning*

[1] The similarity between these results and those reported earlier in this paper is coincidental.

*was so intense, and the collaboration and cooperation used to exercise it was palpable. People enjoyed helping others understand and acquire knowledge, and for any problem you knew who to go to. It was a treasure that I miss frequently.*

- Colin, Celadon alumnus

Colin explains that the line between collaborative learning and helping others learn is blurred and often non-existent. With collaborative learning embedded in the Celadon curriculum, helping peers learn is then also an inevitable part of being at Celadon.

Many of the study participants go on to describe peer teaching as both an honor and something that was expected of Celadon students. Here is how Kristi, Celadon alumna, describes her perception of peer teaching,

*Once at Celadon, NINJAs and the general helpfulness of the community made also participating in teaching-related activities almost run-of-the-mill. Being a NINJA felt like something of an honor, which increased its appeal.*

- Kristi, Celadon alumna

Peer teaching at Celadon then seems to be both a natural choice and an honor to strive for. As such, it is of no surprise that Celadon students not only participate in multiple peer teaching experiences while at the College, they become more motivated to do so in the future. Our quantitative and qualitative data indicate that with the acquired informal and formal (e.g., the *Teaching and Learning* course, educational research) pedagogical knowledge and skills, increased PA, and pedagogical attitudes and behaviors, Celadon students express desire to and, in fact, pursue teaching and teaching-related activities well beyond their four years at the school. The qualitative data above helps in opening a door for understanding the underlying reasons for Celadon students and alumni to do so at a higher rate than the students and alumni from other engineering programs,

*At Celadon it is very clear that each person looks out for [sic] other person, and we have a responsibility to both educate our peers and be open to the teaching of others.*

- Tyler, Celadon student

## V. STUDY LIMITATIONS

While this study has given us much food for thought, it does have some limitations that must be acknowledged, the chief of which is that its sample is drawn from one institution with an arguably unique culture. For example, it is not clear whether Celadon attracts students who are interested in education *a priori*, despite having no explicit goal of doing so or formal teacher training program, or if the apparent effects observed in this study can truly be attributed to Celadon's academic and non-academic culture. This limits the generalizability of our findings and their transferability to other institutions, though institutions may still find the conclusions below of use in planning their own programs.

There is some concern about self-selection bias among subjects, as the entire population was invited to complete the survey, while 28% responded. While the demographic breakdown of the sample was in line with that of the Celadon population as a whole as previously discussed, the survey topic may have attracted those more interested in teaching and related activities, especially among alumni. A review of alumni who, according to Celadon College records, have pursued education-related careers shows that 53% of them responded to the survey, representing 14.6% of study subjects compared to 7.2% of the alumni population. Regardless, the qualitative data present compelling evidence that institutional culture can affect students' attitudes toward education and, perhaps, toward careers in education.

We also have some minor concern that the survey instrument may require revision to one or more questions. Some comments were received in open-ended responses that suggest the need to review the question related to changes in the level of the subject's confidence to teach. Some respondents shared that the act of formal teaching itself lowered their confidence. As this effect was not anticipated in the study design, it may explain why statistical tests related to confidence did not reach the $p \leq 0.05$ significance level.

## VI. CONCLUSIONS AND FUTURE WORK

Although this study did not seek to draw a causal relationship between attending Celadon College and fueling students' interest in teaching and teaching-related activities, our analysis suggests a link between institutional academic and non-academic cultures and interest in teaching. It is clear that the academic culture at Celadon College supports development of students' pedagogical awareness and encourages positive informal peer teaching experiences that may lead to the desire to pursue teaching and teaching-related activities. There is also evidence to suggest that these two factors influence how a student may think about and identify with teaching, teaching-related activities, and research on education, including action research. The connection between these newly acquired ways of thinking and the motivation to teach has not yet been fully explored and will become the topic of future studies that build on this preliminary work.

Moreover, we expect that other institutions may also be providing rich environments in which students develop pedagogical awareness and experience informal peer teaching, which contribute to interest in teaching. Likewise, research at some institutions may result in emergence of entirely different themes. Therefore, to understand the full spectrum of factors contributing to STEM students' interest and motivation to teach, future work may include a range of STEM higher education programs.

Some of the questions remaining for the authors of this work and open to the engineering education community are:

- To what extent can pedagogical awareness be encouraged in diverse academic environments?
- To what extent do different learning environments promote informal peer teaching?

- How does an interest or curiosity in teaching turn into participation in teaching activities?
- How do various motivations for participation in teaching activities affect ongoing and future participation in teaching activities?
- How do various learning experiences, both inside and outside the classroom, contribute to the development of teacher identity?
- Although a teaching career is not for everyone, how can graduates not pursuing teaching activities/careers benefit from the development of pedagogical awareness and teacher identity?

We believe these are just some of the many questions the engineering education community must tackle if we are to fully understand how to prepare the next generation of quality STEM educators.

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