Pre-Service Science Teacher Attrition: Critical experiences, relationships, and timing

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Attracting, retaining, and graduating qualified science teachers are well-documented challenges. Via a sequential explanatory mixed methods study, we followed the educational route of 10 years of secondary science teaching candidates. Descriptive statistics were analyzed with particular attention to the timing of attrition when it occurred. Interviews were then conducted with students from the different outcome groups and researchers used content analysis to identify common themes. Results indicated that attrition, both from the sciences and from the educator preparation program (EPP), occurred quickly – often before traditional support and engagement structures within the program would have had time to work. Findings concluded that specific institutional supports, mentoring support, and peer relationships directly affected students' persistence. In particular, participants who engaged in an NSF grant-sponsored mentoring program demonstrated dramatically higher persistence rates than traditional EPP participants. The research concludes with a list of actionable steps programs might take to support and engage science-teaching majors prior to the timing of peak attrition.

Keywords: attrition; engagement; science teacher preparation; mentoring

Introduction

Nationwide, the number of undergraduate students who earn educator certification or major in education has decreased since 1970 (Possy, 2018) and mirrors the consistent annual increase in teachers who leave education (Sutcher, Darling-Hammond, & Carver-Thomas, 2016). In STEM teaching fields specifically, as the supply of quality mathematics and science teachers languishes, the demand for professionals in mathematics and the sciences continues to rise (National Academy of Sciences, 2010; Watt, Richardson, & Pietsch, 2007). Education experts and researchers argue that these attrition rates will continue to increase due to the stresses educators are under because of COVID-19 (Keown et al., 2020). These challenges, both new and old, put pressure on both K-12 and post-secondary educational structures to recruit and retain mathematics and science teachers with the pedagogical content knowledge and the classroom efficacy to excel and persist in the STEM classroom (National Research Council, 2011; National Academy of Sciences, 2010).

Literature Review

The National Academy of Sciences (2007, 2010) has warned repeatedly of our nation's desperate need for a STEM workforce that will keep pace with project growth in demand, and specifically the shortage of highly qualified STEM educators capable of engendering the interested and cultivating the expertise this next generation of STEM professionals will need. The challenges facing institutions seeking to attract and retain aspiring science teachers are myriad: increasing economic impact of student debt and the rising costs of higher education (Sutcher et al., 2016), an increase in for-profit teacher certification entities, teacher salaries that do not keep up with the cost of living, hyper-accountability organizational structures and micromanagement of teachers, decrease in state and federal education budgets, increased federal and state assessment both in teacher education and in public schools, federal and state political rhetoric that disrespects and commodifies the profession of teaching and public schools, and political efforts to privatize education nationwide (Betancourt, 2018; Zeichner, 2010).

In one instance of the staggering costs related to this endeavour, the Texas Center for Educational Research released a study in 2000 estimating the costs of teacher turnover to the state at somewhere between $300 million and $2.1 billion per year. Had the analysis included the state's costs for training prospective teachers who never certify or enter the classroom, the cost would have been markedly higher.

More hopefully, Watlington, Shockley, Guglielmino, and Flesher (2010) analyzed a large volume of teacher turnover research and concluded that much of it is avoidable given appropriate training and support. Hong, Greene, Roberson, Francis, and Keenan (2018) examined pre-service teacher's processes of choosing and committing to a teaching career. Their research findings indicate that their participants' pathways to choosing and persisting to teacher certification were complex, non-linear, and evolved with social and environmental contexts. They also indicated that the developing personal identity of pre-service teachers was intrinsically connected to their choice of teaching as a career. They state,

> [T]he process of pre-service teachers' career exploration inevitably involves the exploration of various considerations such as sociocultural conditions (e.g. the levels of support from family to friends, financial benefit, and societal perception of the teaching career), specific tasks embedded in the social context (e.g. teaching experiences in

> formal or informal educational settings, learning experiences in teacher education programs), one's own psychological attributes (e.g. self-efficacy and value orientation). (Hong et al., 2018, p. 410)

They argued that prospective teachers need to receive constructive feedback from practitioners they trust. Other research concurs that such support, paired with early exposure to the teaching profession, would improve persistence to graduation (Day, Sammons, Stobart, Kington, & Quing, 2007; Smith & Ingersoll 2004; Darling-Hammond, 2010).

Wang and Grimes (2000), researching in the area of college student retention rather than education, framed retention research in terms of three elements: determining dropout predictors, identifying critical points, and validating outcomes assessment of retention endeavors. Their work built on the work of Levitz and Noel (1985) in aspiring to identify precisely timed interventions for specific subpopulations of students. If the STEM teacher shortage is to be addressed, there must be measurable and attainable steps identified toward the lofty goals of a robust professional community. Wang and Grimes' elements provide a measurable, step-by-step frame for the vocational exploration and interpersonal sense-making recommended by Hong et al. (2018) and Day et al. (2007).

In her dissertation, Groves (2019) concluded that Hispanic STEM teacher candidates were best served by multiple systems of support including peer support, family support Master Teacher support, programmatic support, and financial support. Kuh, Kinzie, Cruce, Shoup, and Gonyea (2006) concluded that the same is true for all college students, arguing robust support systems involving faculty, mentors, and peers benefit *all* students, and particularly students from historically underserved populations. The findings both Groves and Kuh et al., however, remain largely silent on the timing of these supports. Specifically, how long does an institution or a program have to establish engaging support systems with a particular student before that student is likely to leave?

Once pre-service teacher candidates enter the classroom, the character of their preparation continues to have an impact. Latham, Mertens, and Hamann (2015) examined attrition data from over 6,500 teachers in Illinois and found that those teachers prepared through Professional Development Schools persisted at a markedly higher rate than those traditionally prepared. More broadly, Ingersoll, Merrill, and May (2012) examined differences in teacher preparation methods nationally and how those differences affect teacher retention. Their research findings indicate that STEM teachers are more likely to pursue alternative certification routes with lower quality pedagogical content training, and have lower retention rates once they enter the teaching field. Alternative certification pathways often have less field experience and fewer opportunities for candidates to get quality, discipline-specific feedback and mentoring as they pursue their teaching certificate. Ingersoll et al. (2012) found that 24.5% of teachers who have little or no disciplinary pedagogical training leave teaching after one year, compared to 9.8% of teachers who have had a comprehensive pedagogical training. This study may indicate that the absence of a STEM specific EPP at a university contributes to the attrition levels of STEM teachers not only before graduation but also after they enter the profession.

Digging into what specific benefits these programs might provide, Hong's 2010 study attempted to identify specific aspects of pre-service and beginning teachers' professional identities in relation to what caused them to leave the profession. Hong identified six factors: value, efficacy, commitment, emotions, knowledge and beliefs, and micropolitics, through a mixed-methods study that included participant surveys, then interviews of participants at different stages of teaching. Hong concluded that teacher candidates tend to have much more vague concerns about teaching, while in-service teachers tend to have much more concrete concerns. This raises the related question of which specific interventions might best assist teacher candidates in anticipating and preparing for the more concrete concerns of their future colleagues. Still these studies rely largely on general characterizations of the teacher candidates' educational experiences, while Wang and Grimes (2000) recommend very specific time-bound identification of issues for specific subpopulations.

In a recent study of STEM majors' and graduates' attitudes towards pursuing a teaching by Marder, Brown, and Plisch (2018), STEM majors indicated that in order to pursue a teaching career through a university, they would need (1) financial incentives, (2) faculty in content departments to discuss a teaching career as a positive career choice, and (3) more information about teaching salaries and benefits. This research points to specific interventions for universities seeking systemic improvement in recruiting and retaining STEM teaching candidates. Marder et al. (2018) recommended that university EPP's and disciplinary departments

> Impress upon university faculty and advisers in STEM disciplinary departments the importance of promoting middle and high school teaching with their undergraduate majors and graduate students, and of providing them accurate information about the actual salary and positive features of teaching (p. 27).

The survey respondents in the Marder et al. study indicated that they would be more interested in pursuing a teaching career if there was access to a STEM specific teacher certification program at their university, if teachers earned a higher salary, if there were student loan payoff, tuition, or scholarship incentives attached to getting teacher certification, and if the teacher certification added less time to their degree plan. These factors likely contribute to the attrition rate of STEM majors from EPP programs at most universities. These studies highlight the need for additional work to identify events and critical points that influence attrition while attending to relational supports that foster persistence.

Theoretical Framework

Conceptual Model

In the field of higher education retention, Levitz and Noel (1985) proposed a popular theoretical framework, based on Forrest (1982), which conceptualized retention research as inextricably connected to action. Their six objective framework was:

1. To study success – to find out what the institution is doing well in order that it may do more of it;
2. To pinpoint campus services that need further attention so that they may be improved;
3. To determine the type of intervention programs and practices that are linked to student success and student persistence;
4. To follow those students who receive special attention or participate in special programs to determine whether the intervention is having the desired impact;
5. To target students who will benefit from interventions known to have a positive impact;
6. To provide validation of the outcomes that an institution is striving to achieve (Levitz & Noel, 1985, p. 350).

Wang and Grimes built on this framework by identifying three major components within retention research: determining dropout predictors, identifying critical points, and validating outcomes assessment of retention endeavours. The wrote, 'Retention research should promote a spirit of continual improvement instead of just seeing what went wrong … the data gathers should serve as a catalyst for intervention as well as for administrative policy making.' (2000, p. 61)

The Wang and Grimes (2000) framework lends itself to an explanatory mixed methods approach. Initially, we gathered student performance data captured for all university students to identify dropout predictors and the timeframes in which particular attrition patterns most frequently take place. However, the Wang and Grimes framework also recommends examining non-cognitive factors such as social motivation and receptivity to institutional support services, which are better identified through interviews and qualitative data analysis rather than institutional datasets.

This methodological framework allowed us to examine aggregate science major quantitative data, then move to a qualitative analysis of a small cross-section of those students to ‘explore the participants views in more depth’ (Ivankova, Creswell, & Stick, 2006, p.9). An IRB was obtained at the university where the study was completed to ensure the protection of student rights.

Methodology

Utilizing a mixed-methods approach this research study is framed at the intersection of the fields of science education and research in student engagement and retention. This study sought to address the following research questions:

1. What pre-service science teacher attrition patterns exist at our public regional comprehensive university?
2. What social and experiential factors influence undergraduates pursuing science teacher certification to change majors, not certify, or choose other certification pathways?
3. What is the timing of major change or change in certification pathway if it occurs?

This study first analyzed all declared science teaching majors over the past decade at our state university, attending to their persistence pattern in science, their persistence pattern in education, and the timing of any change in course. Through this analysis a disparity between students in the Robert Noyce funded NSF STEM teacher recruiting and support program, and students outside the program was identified. Students in the NSF program were four times more likely to graduate certified to teach science as those outside the program. Following the data analysis, participants were interviewed who were a part of three key outcome groups: science teaching majors who left the sciences, science teaching majors who persisted in science but left teaching, and science teaching majors who persisted in science teaching. The influences of peers, mentors, and faculty, either toward staying or leaving, appeared repeatedly in the qualitative analysis of interview data.

Context and Participants

This research was undertaken at a rural comprehensive university which was founded as a teacher's college. With an enrolment of roughly 13,000, approximately 50% of the university graduates report being the first in their family to graduate from college, and just over 70% of STEM majors qualify as Pell Grant eligible. The university offers undergraduate science certifications in Biology and Chemistry. At the time this research was undertaken, these certifications included a major in biology or chemistry taught exclusively by the Department of Biology or the Department of Chemistry, respectively, then eight additional courses in an Education Preparation Program (EPP) taught exclusively through the College of Education. The traditional EPP pathway included mandatory field experience in six of the eight courses but did not include an early intense field experience component, consistent mentoring by faculty or mentor teachers, or a peer support network.

Additionally, STEM teaching majors could apply to participate in The National Science Foundation Program Talented Teachers in Training for Texas (NSF 1136416, NSF 1556983), T4 for short. T4 Scholars are STEM majors who apply to the program and are selected based on GPA, professor recommendations, essay, time to graduation, and responses during a face-to-face interview.

T4 is a Robert Noyce Scholarship initiative based at the university with the goals of:

1. Creating experiences through which university STEM majors can examine careers in high school teaching through early intensive field experience (author, 2015);
2. Targeting aspiring STEM teachers for authentic engagement in a community of practice with a structured mentoring network (including experienced classroom teachers, aspiring STEM teachers, and STEM and education university faculty) for two years before graduation and three years after entry into the teaching profession (author, 2013);
3. Longitudinally examining prospective STEM teachers for the purpose of identifying most effective practices in long-term STEM teacher training and retention.

During their undergraduate coursework, T4 pre-service teachers receive biweekly mentoring and training while undergraduates, regular mentoring from STEM and education faculty members, a STEM expert supervising teacher during student teaching, induction mentoring once they enter the classroom, and sizable scholarships equivalent to roughly three years’ tuition. T4 Scholars commit to regular participation in the mentoring network community and four years of teaching in a high-need school district. Scholars also have opportunities to attend discipline specific state conferences as well as regional and national Robert Noyce Conferences.

Data

Our initial data gathering included quantitative academic performance data for all biology and chemistry majors who had attended the university since 2007 and who had at some point identified secondary education as a minor or emphasis. For these 97 students, we tracked graduation rates, secondary education courses taken, and majors and minors declared or completed. Parallel data was also gathered for all mathematics teacher majors, believing this to be the most similar teaching population within the university and hoping to use that population's attrition patterns might serve as a reference point for pre-service science teacher attrition patterns.

Our framework called for specific attention not only to *what* predictors of attrition existed, but also *when* particular attrition patterns took place. Since different students started in different academic years, we measured time units in either semesters since beginning at the university or number of courses, depending on the context of the variable.

Finally, data from the Texas Education Agency (TEA) was also examined in order to identify which science and math teaching majors went on to teach in a Texas public school setting, even if they did not get certified at the university.

This quantitative data analysis culminated in the identification of three emergent groups with differing characteristics based upon persistence to graduation or certification, these groups were:

1. Science teaching majors who had persisted to certification and a degree in major;
2. Science teaching majors who had persisted to a degree in major without certification; and
3. Science teaching majors who had not persisted to degree in major.

Student Interviews

To more thoroughly understand what influenced science teaching majors toward persistence or change of major or career, and to more adequately understand their perceptions, interviews were conducted with individuals representing each of the identified three key groups of students from the data analysis.

Interviewees were selected from three identified categories based on the descriptive data analysis of the 97 science majors. Within each category, interviewees were contacted in order of most recent enrolment at the university. This criterion was intended to maximize the relevancy of feedback to current university programs and shortcomings, as well as to maximize the likelihood potential interviewees would respond to a request for an interview. If a potential interviewee did not respond after three attempted contacts, they were replaced with the next most recent candidate in that category.

Seven individuals were interviewed by three different faculty members using the same semi-structured interview questions. Interview questions (see Appendix) were designed to identify critical experiences within candidates' educational journeys, along with how they interpreted those experiences. The questions were based upon the theoretical framework of Wang & Grimes (2000) and designed to identify key points in persistence or attrition for the participants. The interviews focused particularly on challenges during the students' certification pathway, and what influences had positive or negative impacts on their choices to persist in STEM teaching, and how those influences helped the participant's choose to not certify to teach, or choose another major. Interviewees were offered the option of a phone interview or a face-to-face interview.

Data Analysis

The mixed method analysis began by a quantitative examination of existing institutional data along with the data from the TEA. Descriptive statistics were calculated with particular attention to timing of attrition actions.

After identifying descriptive trends, participants were identified for qualitative interviews to more robustly explain these patterns via interviews. The interviews were recorded, transcribed, and coded independently by three researchers to identify themes through open coding. Interviewers took written notes during the interview, which were scanned and compared to the open coding to improve fidelity of analysis. Common themes were compared between all three researchers to ensure trustworthiness and dependability (Lincoln & Guba, 1985).

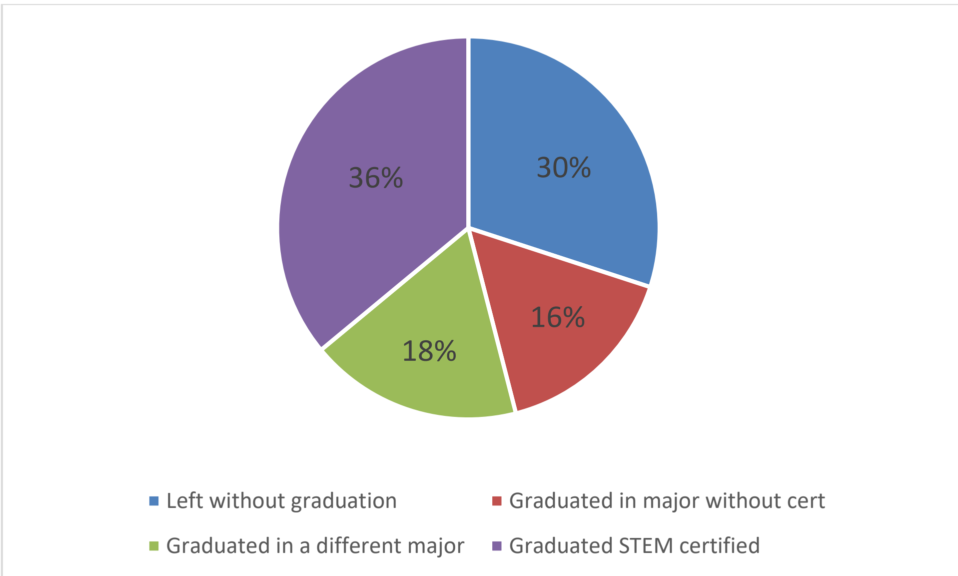
Results

Attrition Themes within the Quantitative Data

Institutional data was gathered for 97 science majors with secondary teaching minor or concentration since 2007. Of those students, 36 students were still enrolled as undergraduates at the university when the study began, meaning that most calculations focused on the 61 students who were no longer enrolled. Of those 61 students, 49 initially declared biology as a major while 12 began in chemistry. Over the same period there were 1,170 biology majors and 171 chemistry majors at the university, so these STEM teaching majors made up only 4.2% of the biology population and 7.0% of the chemistry major population before attrition.

Of the 61 science teaching majors, 22 students, or 36%, graduated in their science majors and certified to teach. Eighteen, or 30%, left the university without graduating. Ten students, or 16%, graduated in their initially declared major but did not complete the teacher certification coursework. Eleven students, or 18%, graduated in a different major than initially declared. We sought a pattern within the group that changed major, but found none. Two majors switched to interdisciplinary studies, while one major each went to geology, accounting, creative writing, environmental science, mathematics, communication studies, finance, hospitality administration, and kinesiology.

Figure 1. Outcomes for aspiring science teaching majors by percentage



These persistence and attrition patterns are summarized in Figure 1. Roughly one third graduated prepared for science teaching, one third graduated but left the educator preparation program, and one third did not graduate. This pattern was then compared to the same populations for mathematics teaching majors at the university over the same period. Beginning with 164 mathematics teaching majors who are no longer at the university as undergraduates, 28% graduated in major and certified to teach, 31% graduated but left the educator preparation program, and 41% left without graduating.

The rate at which this same population of students taught in a Texas public school was examined. This analysis required removal of the 12 individuals who had discontinued (by graduation or otherwise) their university education within the last year, since these individuals have not yet had the opportunity to teach for a year. Of the remaining individuals (n=49), 18% of those who left the university without a degree taught in a Texas public school; 39% of those who graduated but did not certify taught in a Texas public school; and 80% of those who graduated certified taught in a Texas public school. These percentages are almost certainly lower than actual entry into the teaching profession since it does not include those who taught in private school, those who taught outside of Texas, or those will go on to teach after this study is completed. However, since the measurement is the same across all three groups, teaching in a Texas public school is arguably a meaningful relative measure of entry into the teaching profession.

Table 1. Teaching outcomes of former science teaching majors by college outcome

Status leaving university	**Percentage who taught in Texas Public Schools**
Without a degree (completed degree elsewhere)	18%
Graduated but did not certify through EPP	39%
Graduated in STEM with an EPP cert	80%

Attrition as related to the T4 students

The analysis above neglects, however, to illuminate one important aspect of the persistence puzzle. Since 2012, 13 science teaching majors participated in the T4 program as a supplement to the EPP and received the additional supports from that program. Four of these students are still enrolled and the other 9 have *all* graduated in major and certified. Removing these 13 students from the general science teaching population makes the contrast more extreme. Figure 1 summarizes the attrition and persistence outcomes of both T4 and non-T4 students but disaggregated. While it appears from Figure 1 that the most common outcome for a science teaching major is to leave without graduation, Table 2 clarifies that this is only the most common outcome for non-T4 science teaching majors. For T4 science teaching majors, the *only* outcome is to graduate certified. This comparison of traditional certification pathway and the T4 certification pathway aligns with Wang and Grimes (2000) theoretical framework which recommends validating outcomes assessment of retention endeavours, such as the T4 Noyce scholarship program.

Table 2. Comparison of academic outcomes for T4 and Non-T4 science students

	Graduated science, Certified in science	**Graduated Science, No Cert**	**Graduated, Not in Major**	**Left Without Degree**
Non-T4 Science Students	25%	19%	21%	35%
T4 Science Students	100%	0%	0%	0%

Attrition Timing within the Quantitative Data

Following the framework of Wang and Grimes (2000) that recommends determining dropout predictors, identifying critical points in the EPP, the timing of attrition from either the EPP coursework or the science major coursework was examined. During the traditional EPP, we examined attrition during the number of courses completed within the EPP. As Table 3 outlines, attrition is heaviest within the first two education courses. Of those who did not complete the program, 77% left before beginning the third course. For those that entered the third education course, the likelihood of completing the EPP course of study was 71%.

Table 3. EPP courses passed before leaving program or leaving university (n=42)

EEP Courses	Number of students	Percentage of students
0	7	17%
1	8	19%
2	19	45%
Application to EPP		
3	1	2%
4	4	10%
5	0	0%
6	0	0%
Application to Clinical Teaching		
7	3	7%

The same method to identifying points of attrition during the science major coursework was applied. Both the number of semesters students persisted in major before switching and the number of science courses students took before switching were examined. The analysis was restricted to science teaching majors who switched major or left the university entirely. Over the course of the study, 29 individuals fit that category. Table 4 summarizes the number of semesters that a science major identified themselves as being the giving majors before switched major out of science or leaving the university. Notice that the median is only two semesters, and the mode is one semester. (For the sake of this analysis, the summer was interpreted as a semester if students were enrolled for at least one course.)

Table 4. Semesters in major before switching major or leaving university (n=29)

Semesters	Number of student	Percentage of students
1	10	34%
2	8	28%
3	4	14%
4	4	14%
5	2	7%
9	1	3%

Similarly, in Table 5 the number of courses successfully completed by science teaching majors who left their major field of study or left the university was examined. Again, the median number of science courses is telling. This subpopulation successfully completed an average of just one science course, counting those inside or outside their major, before switching major or discontinuing at the university entirely.

Table 5. Science courses passed before switching major or leaving university (n=29)

Science courses	Number of students	Percentage of students
0	8	30%
1	9	33%
2	5	19%
3	2	7%
4	0	0%
5	3	11%
6	2	7%

Themes within the Qualitative Data

Several themes emerged from the interviews with science teaching majors across the persistence spectrum. The first theme was a skeptical view of EPP coursework. In five of the seven interviews, various types of skepticism emerged about the coursework. Two argued the EPP coursework was “overly general” or “unfair” because there were no specific resources provided for passing the science certification exams. Two others questioned how much they were learning, even as one of those interviewees praised their individual instructor. One stated, “It felt too easy… I don’t think I was being challenged.” Another recalled, “I was really bored in my secondary education classes. I didn’t feel like they were very challenging, and I like a good challenge. So, that’s when I decided to switch over.”

The EPP at the university did not offer a science teaching methods course, so students’ dissatisfaction with the curriculum of the EPP might be expected for students who are working to certify to teach science (Marder et al., 2018).

It appears plausible that STEM teaching majors, having gravitated toward highly quantifiable fields and having been enveloped in an educational environment where ‘what is tested’ is deemed most important, did not attach high value to the EPP training with its focus on sociological or psychological course content such as ‘culturally responsive pedagogy,’ ‘sociocultural and historic perspectives,’ etc. This viewpoint is common for pre-service teachers who never experienced STEM classes that utilized culturally responsive pedagogy or practical and sociocultural application to course content (Koch, Carrier, & Walkowiak, 2017). It is easy to understand how these students might reasonably ask if there exists a quantifiable benefit to traditional undergraduate certification as opposed to certification by another means.

A second related theme emerged among the participants: students who left teacher preparation had limited mentorship or role models in the teaching profession. Not a single participant who left the STEM teaching career path indicated that anyone had been concerned to see them go. The closest was one student who indicated that her parents had originally liked the idea of a career in teaching because ‘they wanted me to stay close to home.’ On the contrary, most participants who left teaching experienced only attitudes of indifference about teaching and most who left biology or chemistry experienced no encouragement to stay from faculty, family, or friends. One shared, “It felt like an unknown field to me” despite having been in the program for a full year and taken multiple biology courses. Another participants recalled a faculty member saying to her, ‘I’m sorry you’re not competent to get through courses.’ That student did persist in course work, but in a different major.

In all five interviews with participants who left the EPP, no STEM teacher had established an ongoing relationship with the student. Several mentioned positive experiences and interactions with STEM and education faculty members, one saying they were ‘very supportive’ but this support was not a concerted, continuous one.

Another participant revealed that they were discouraged by the fact that after years of being a STEM major, faculty in her major discipline still did not know her name. Only one participant described an instance where a faculty had encouraged them to teach.

In contrast, interviewees with participants who persisted to teaching mentioned professional mentors and also faculty encouragement. These students described being a part of Talented Teachers in Training for Texas (T4) as a positive influence in very specific and individualized ways. One recalled her T4 education professor, she “is always really supportive just always encouraging me like ‘you’re doing really well,’ ‘you could improve on this,’ and ‘this is how you can do this.’ She was always there and available to help or just whatever you needed.” The other graduate highlighted the contrast, “Like not once did we ever talk about, other than T4, talk about lab safety and what I need to do and how to approach [science teaching] in my classroom.” It is noteworthy that one of these two participants mentioned a faculty member telling her, “You have so much potential to do something else [besides teach].” But it appears for this student that the positive influences toward teaching had a greater impact than the advice to pursue a different career.

A third related theme emerged: students’ decision to persist often hinged on one person’s input or influence from individuals with limited knowledge of STEM careers or teaching. One student who switched to nursing indicated that college friends in the nursing program were the primary influence to switch majors: “I decided to switch to nursing I think because my friends [in nursing], they would ask me for help. They were taking anatomy and physiology which I had already taken in high school as dual credit and I like those classes more than the ones I was taking myself." These individuals were peers who had never experienced the nursing profession or any other, and ironically ended up switching out of nursing themselves.

Another participant switched to health sciences because her roommate seemed to like it: "My roommate, who is also one of my best friends now, she is a dietetics major. I was watching her work and what she was doing which was really cool and that also influenced me as well." Another was encouraged to pursue teaching by her mother because "teaching is a better job for a mom." Although she did not certify as an undergraduate, she did go on to teach for three years.

Multiple participants described great uncertainty and repeated changes in direction surrounding their major course of study. It appears that in the absence of clear, objectively knowledgeable experience or direction, students are open to whatever major directions their social circle has to offer.

Discussion and Implications

Student Implications

The research findings indicate that aspiring science teachers are at a high risk of attrition from the beginning of their undergraduate experience. Numerically, science teaching majors outside the T4 program were only one fourth as likely to persist to a science degree and a teaching certification. These results appear quite similar to the results of aspiring mathematics teachers as well, so there is every indication that the concern is broader than just science teaching.

The timing of student attrition indicates that most students who leave the sciences do so in the first year and after only completing an average of one science course. Students who leave the EPP typically leave within the first two courses. Based upon these pinpointed times within the undergraduate experience, intervention needs to be quick and likely initiated based off of a student's declaration of a science teaching major rather than passively off of a student's getting to a particular point such as a course, EPP admission, or classification designed to engage or support science teaching majors.

The data also indicates that students who leave the EPP do not appreciate the intrinsic value of the formal teacher preparation and do not see the extrinsic value of formal teacher preparation, especially when it is removed from the content area that the student is interested in teaching. This aligns with the findings of Marder et al. (2018) whose research findings indicated that STEM majors were more interested in teacher preparation programs that were specifically geared to their major and teaching area. Interventions that can intertwine both content area and EPP programs could negate the perception of disconnect between general education preparation and content specific curriculum.

Program Implications

The research findings indicate that beginning students are often quite impressionable in their choice of career and major. Within the university EPP in the study, there is a dearth of influence from practicing science teachers or those who highly value the profession, at least outside of the T4 program. One clear implication is that programs seeking to address attrition should proactively connect with students who declare an intent to pursue science teaching rather than reactively wait for students to take a certain course, reach a certain level, or connect to community themselves. A fruitful goal for systematic program efforts should include connecting students with a declared intent to teach science with individuals who value and are knowledgeable about both the sciences and the teaching profession. Additionally, the findings indicate that peers often have an outsized influence on career path as well, so facilitating this type of engagement in a venue where science teaching majors could connect with other science teaching majors would potentially have a compounding effect.

Proactive and early intervention is exactly the type of engagement described by those within the T4 program. The program connects aspiring STEM teaching majors outside the classroom with STEM teachers, administrators, and those who highly value the teaching profession. Further, programs events connect aspiring STEM teachers to others with the same declared interest, lending their aspirations legitimacy and creating a peer mentoring ethos. The program evidenced a 100% rate of science graduation and certification, which is four times the success rate of science majors seeking certification outside the program.

Specific actionable implications, modelled off of the T4 program, might include:

- actively contacting science teaching candidates in their first semester in major welcoming them and making them aware of activities available to science teaching candidates;
- providing social events early in the semester targeting new science teacher candidates to build community with experienced science teacher candidates, mentors, etc.;
- offering opportunities to experience real classrooms early in their course of study without long-term commitment (for some students even commitment to a 16-week course may be too high a threshold);
- bringing new science teachers, veteran science teachers, and principals to campus to interact with prospective teachers;
- providing short professional development sessions for science teachers that explicitly include aspiring science teachers;

- providing intrusive advisors who meet with science teacher candidates multiple times a semester, communicate the value of science teaching, ask specific questions about student success, and have the time to assist both in planning coursework *and* cultivating students' professional identity;
- having advisors, science faculty, and education faculty meet to discuss specific students' progress and risks
- discussing context specific ways to provide science teaching majors the time and relationships formulate self-identity as science teachers.

Additional Discussion

One theme identified in the interviews that bears addressing was skepticism over whether traditional undergraduate teacher certification yielded any quantifiable value for science teaching majors. Although it might be argued that students should be concerned about more than 'quantifiable value,' the question of quantifiable value should be addressed. Utilizing Texas Education Agency data on Texas public schools in parallel with university records, over the past decade only 1% of those entering the university as a STEM major certified to teach as an undergraduate. In contrast, 10% of those same students ended up teaching in a Texas public school. Which teachers persisted in their career? Restricting our attention to STEM majors who enrolled Fall 2007 or after, then graduated or discontinued Summer 2012 or before, we examined five-year retention in a Texas public classroom. For those who did not earn an undergraduate certification, the five-year retention was 37%. Of those who earned undergraduate certification, the five-year retention was 88%. (We note again that this data only considers public school teaching in Texas as proxy for actual teaching and retention rates. Also, the term 'five-year retention rate' is used to denote the percentage of those who taught at least one year in a public school that taught at least five years in a public school.)

Clearly, a vast quantifiable distinction exists between retention rates of teachers who chose a traditional undergraduate teacher certification and those who chose an alternative certification. This fits with the research of Ingersoll et al. (2012), Redding and Smith (2016), and Zhang and Zeller (2016) whose findings indicate that traditionally certified STEM teachers stay in the teaching fields longer than those from alternative certification programs. However, the fact that students seemed uninformed about the benefit of the program in terms of longevity in the profession speaks to a programmatic consideration. It appears there are no systematic mechanisms in place to communicate the value of traditional certification to science teaching majors (or any other majors). This evidence appears highly relevant to students' best interest and career prospects. Programs must work to clearly communicate the tangible value in terms of teacher retention that comes from their program. When considered in light of the relatively small number of education courses taken by those who left teacher certification, the urgency of addressing this issue *as soon as a student self-identifies as intending to teach* seems critical. The information is exceedingly relevant to students and most institutions have such data or could get it for their specific student population.

These results are similar to the findings of Marder et al. (2018) in suggesting that STEM majors might be more interested in teaching if they received more information and additional support regarding STEM teaching. In their work they found that students were ill-informed about the salary levels of STEM teachers and would have been substantially more interested in the career possibility if they had access to more accurate and readily accessible information about STEM teaching as a career.

Conclusion

If universities are to improve science teacher attrition rates, it is critical that programs must proactively engage these students with an eye toward the timing and the engagements that might serve them best. This research study results correlate to Hong et al. (2018) in suggesting that peer groups, family, and faculty are vital to the decision-making process of pre-service teachers as they choose to persist or drop out of EPPs. But given that universities do not control family and that in-class faculty connections often appear too late an intervention, there is a need to develop comprehensive ways to connect students to faculty and mentors, along with providing potential connections to peer groups in science teaching that will best support science teaching majors' stated career aspirations. Programs must critically examine the timing of attrition points and peer social interactions with humble candour, and address existing structures that fail to serve students in their time of most need for engagement. Change at the university level must include specific evidence-based interventions and a systemic and institutionally funded support pathway including mentoring, peer connections, experiential learning, and interaction with practitioners in the field. The field of teacher education is facing challenging times in the midst of a global pandemic but perhaps these uncertain times can serve as a catalyst to examine and alter teacher education to decrease attrition.

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Appendix - Interview Protocol

0. First, thank you for taking the time to do this interview. I just wanted to confirm that you received the informed consent via email and that you agree to let us use your answers anonymously.

1. Initially you registered as a science major planning to certify to teach, but then you changed course. When did you first decide to pursue a different path?

2. What influenced that change in direction?

3. Were there any obstacles or barriers to certifying in science teaching that contributed to that decision?

4. How did peers or family influence your career choice, both initially and as it changed?

5. How did faculty or professional mentors affect that change?

6. Looking back, do you have any regrets about your major and career choices? Explain.

7. Are you or would you consider teaching in the future? Why or why not?