Abstract

Title of Dissertation: FROM DICHOTOMY TO CONTINUUM: LINKING THE RECRUITMENT AND RETENTION OF SCIENCE TEACHERS

Ashley Nicole Coon, Doctor of Philosophy, 2022

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High schools throughout the United States, especially those serving high poverty and high minority communities, struggle to find qualified science teachers to fill vacancies, a situation that has been further exacerbated by the COVID-19 pandemic. This science teacher shortage is caused by a combination of low levels of recruitment into the profession and high levels of attrition from the profession, which has led those hoping to ameliorate the shortage to focus on either increasing the recruitment of pre-service teachers into science teacher preparation programs or improving the retention of in-service science teachers in the field. Instead of viewing these two ends of the so-called science teacher pipeline as distinct and dichotomous, the primary goal of this two-paper dissertation is to explore and characterize the connection between the recruitment and retention of science teachers. In the first paper, a content analysis approach is used to identify the factors that motivated six science undergraduates to apply to a secondary science teacher preparation program and compare their motivations to those described in the literature. In the second paper, a multi-case study is conducted to determine how the science teaching commitments of six pre-service science teachers changed over the course of their science teacher preparation program and to identify

the elements of their science teacher preparation program that contributed to changing commitments to science teaching. By drawing upon the findings of both papers, this dissertation argues that there is a link between science teacher recruitment and retention, and it lies in the conversion of interest in science teaching into commitment to science teaching. This connection positions science teacher preparation programs not only as instruments of science teacher recruitment, but also as a first line of defense against science teacher attrition.

Keywords: science education, teacher shortage, teacher recruitment, teacher retention

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Chapter 0: Personal Statement

My interest in the recruitment of science undergraduates into science teaching arose circuitously through my experiences in three different graduate assistantships, all advised by Dr. Diane Jass Ketelhut. During my first semester as a doctoral student, I worked as a research assistant for Dr. Ketelhut and I was asked to implement a pilot study in which prospective science education students participated in a science research experience. The goal of the study was to determine whether participation in science research impacted the participants' science teacher self-efficacy, science inquiry self-efficacy, and career interests. Since mastery experiences are the most potent source of self-efficacy beliefs, and self-efficacy beliefs predict future behavior (Bandura, 1977), we expected that successful completion of the research project would lead to increases in science inquiry and science teacher self-efficacy, which would in turn lead to increased interest in science teaching. However, contrary to our expectations, we found that students who were not committed to becoming science teachers became less interested in pursuing a career in science education after the research experience, even though their self-efficacy scores increased and they reported positive feelings about the experience. To begin making sense of these findings, Dr. Ketelhut suggested that I conduct a literature review to explore what has been written about recruiting science majors to become science teachers. A review of the literature revealed that surprisingly little is known about this subject.

I gained further insight into the recruitment of science undergraduates into science education as an administrative assistant for the Department of Teaching and Learning, Policy and Leadership's Secondary Education Committee, of which Dr. Ketelhut was the chair. One of the tasks of the committee was to track the enrollment numbers of the different secondary

education programs. There was particular concern about the science education program, which consistently had the lowest enrollment of any of the secondary education specialties. Dr. Ketelhut asked me to learn more about the University's efforts to recruit students into the science education program. I began by interviewing Jessica Bancroft, the College of Education's Director of Admissions and Recruitment, because she was identified by numerous committee members as the person most knowledgeable about science recruitment. I also interviewed Dr. Anisha Campbell, the Associate Director of the University of Maryland's Terrapin Teachers program, a UTeach-based science and mathematics education recruitment program, because Dr. Campbell was identified by Jessica as the person most knowledgeable about the University's science recruitment efforts. I learned that all the strategies recommended in the literature on science education recruitment were being used by the University, in addition to several other novel strategies based upon explicit and implicit assumptions about the values (ex: commitment to social justice and/or equality), priorities (ex: salary v. work-life balance), and needs (ex: care and/or support) of undergraduate science majors.

The third and most formative experience that contributed to my interest in science education program recruitment occurred during my second year as a doctoral student, when I worked as a teaching assistant in Dr. Ketelhut's science teaching methods course. This course was often the first education class taken by prospective science teachers and attracted undergraduate science majors with varying levels of interest in science teaching, since it also satisfied an elective requirement. Although my formal role was that of "TA," Dr. Ketelhut gave me the option of serving as a co-teacher of the course, which enabled me to develop deeper relationships with our students. Inspired by the literature review and interviews I conducted

for my other assistantships, I asked our science teaching methods students to complete a survey and an interview about their experiences in science and their motivations to pursue (or not pursue) science teaching. Only students from the course who had decided to apply to the science education program consented to participate, yielding a cohort of six prospective pre-service science teachers. I conducted the interview during the semester after our course and analyzed the interview data over the next few months. I presented my analysis at the 2016 NARST convention.

Until the NARST convention, I doubted the significance of the work I had done around science teacher recruitment, wondering if it was of interest to anyone other than myself. However, the response to my presentation was overwhelmingly positive; it was evident that others were interested in knowing more about recruitment into science teaching. Even more importantly, I was surprised by my own excitement about the presentation, which inspired a passion toward the subject of recruitment that had been lacking before. Ultimately, the analysis that I presented at NARST developed into the paper that is included as Chapter Three of my dissertation proposal and inspired me to further pursue this line of research. In addition to the first interview conducted immediately after our science teaching methods course, I completed a second interview with the members of my cohort, conducted before their graduation from the science education program. An analysis of the second interview data will form the basis of Chapter Four of this proposal. My relationship to the data that I present in the two papers included in my dissertation is enriched by my relationship to the cohort of teachers from whom I collected this data. Although I began as their teacher, in the ensuing four years I have become

a recommender for job applications, a mentor for graduate school decisions, and a colleague, as several have spoken to my subsequent science education students.

Chapter 1: Introduction

Science teacher recruitment and retention represent two attack points for those hoping to improve the quality of science education in the United States through increasing students' access to highly qualified science teachers. When I began the research project that would ultimately give rise to the papers included as Chapters Three and Four in this dissertation, I was focused solely upon science teacher recruitment rather than retention, but I increasingly suspected a connection between these oft polarized ends of the science teacher supply chain. The primary goal of this dissertation is to explore and characterize the connection between the recruitment and retention of science teachers. In this chapter, I will first draw upon the literature to justify my interest in science teacher recruitment and retention, and then summarize what we currently know about science teacher recruitment and retention.

Why do science teacher recruitment and retention matter?

There is a nationwide shortage of qualified secondary science teachers (Cross, 2017; Ingersoll & May, 2012; Moin et al., 2005; Sutcher, Darling-Hammond, & Carver-Thomas, 2016); as a result, high schools struggle to find qualified science teachers to fulfill vacancies (Cross, 2017; Kahle & Kronebusch, 2003; Sutcher et al., 2016). Despite provisions in the No Child Left Behind Act (NCLB) of 2001 and the Every Student Succeeds Act (ESSA) of 2015 requiring teachers to be "highly qualified" in the subjects they teach, the shortage of secondary science teachers continues to lead schools to fill vacant science teaching positions with out-of-field teachers (Hill, 2011; Nixon et al., 2017). The shortage of qualified science teachers is further exacerbated by attrition (Ingersoll & May, 2012). The lack of qualified science teachers is of

concern, since “research has consistently supported the relationship between teacher quality in science… and student achievement” (Liou et al., 2010, p. 452).

While science teacher shortages are reported in virtually every part of the United States (Cross, 2017), shortages are most pronounced in schools serving high minority and/or poverty areas (Sutcher et al., 2016). Students from these schools are the least likely to be taught science by qualified, in-field teachers (Sutcher et al., 2016; Kahle & Kronebush, 2003). Wilson et al. (2004) explain that science teacher shortages “create a ‘buyer’s market’ for these positions” where “wealthy suburban districts have the edge over large urban districts that are not well positioned to offer financial or other incentives… to attract teachers” (p. 150). Further, Ingersoll (2001) describes a ‘revolving door’ where science teachers tend to move on to other, more profitable careers and urban teachers tend to move on to suburban schools; for urban schools, this double ‘revolving door’ further exacerbates their difficulties in finding and retaining qualified science teachers.

The most commonly cited reason for the shortage of qualified secondary science teachers is economic. Most, if not all, nationally recognized teacher preparation programs require prospective secondary science teachers to hold a bachelor’s degree in their content area. However, a bachelor’s degree in science opens up multiple career options, nearly all more financially rewarding than teaching (Kahle & Kronebusch, 2003; Martin & Mulvihill, 2016). It seems unlikely that teachers’ salaries will increase to more competitive levels in the near future, as the national average teacher salary has actually decreased since 2000 (National Education Association, 2013).

Teacher salary does not only impact the supply of qualified secondary science teachers by dissuading science majors from pursuing teaching; it is also one of the factors contributing to attrition among secondary science teachers (Ingersoll & May, 2012; LaTurner, 2002; Tai et al., 2007). Ingersoll and Perda (2009) have demonstrated that the number of new science teachers produced each year is sufficient to fill teaching vacancies due to retirements, leading them to conclude that the shortage of qualified secondary science teachers is not a problem of supply but one of retention, although this assertion has been challenged more recently by Goldhaber et al. (2014). However, as the factors contributing to science teacher attrition (salary, job satisfaction, etc.) are not likely to be rapidly ameliorated, identifying ways to attract and recruit more desirable science majors into science teaching preparation programs will be necessary to address the persisting shortage of science teachers.

What do we know about science teacher recruitment?

If the nationwide shortage of qualified secondary science teachers is to be reduced, schools of education must recruit more undergraduate science majors into science teacher preparation programs. To accomplish this goal, those administering science teacher preparation programs must know when potential recruits are likely to develop interest in science teaching, what factors are likely to impact potential recruits' interest in science teaching, and how to leverage that knowledge into effective recruitment strategies. Currently, there is a lack of consensus in the literature as to when interest in science teaching develops. A review of the literature reveals a wide range of factors underlying the decision to pursue science teaching. The two reasons most often given by pre-service and in-service science teachers to explain their decision are an affinity for science (Bull et al., 1994; Dawson, 2007;

Dominguez et al., 2015; Eick, 2002; Espinet et al., 1992; Kilinç & Seymen, 2014) and a desire to make a positive impact on youth and/or society (Bull et al., 1994; Dawson, 2007; Dominguez et al., 2015; Eick, 2002; Kilinç & Seymen, 2014). Additional reasons cited by multiple studies include a desire to work with youth (Bull et al., 1994; Dawson, 2007; Espinet et al., 1992; Kilinç & Seymen, 2014, Westerlund et al., 2011), positive prior teaching experience (Dawson, 2007; Kilinç & Seymen, 2014; Luft et al., 2005; Wang, 2004), positive impact by a former teacher (Dawson, 2007; Tomanek & Cummings, 1999), valuing the teaching profession (Dawson, 2007; Dominguez et al., 2015; Espinet et al., 1992; Kilinç & Seymen, 2014), and an opportunity to engage with science (Eick, 2002; Tomanek & Cummings, 1999). While factors pertaining to the job conditions of teachers were cited as deterrents to the pursuit of teaching in all studies conducted in the U.S., job conditions (such as salary, demand, and workload) were identified as having a positive impact in the four relevant studies reviewed that were conducted outside of the U.S. (Dawson, 2007; Dominguez et al., 2015; Kilinç & Seymen, 2014; Wang, 2004).

There has been much less research conducted to identify the reasons why potential pre-service science teaching candidates are discouraged from becoming teachers; however, that which does exist tells us that this is due primarily to low teaching salaries and classroom management concerns (Evans, 1987; Worsham et al., 2013). Additional reasons include discouragement from family and friends (Evans, 1987) and difficulty incorporating teacher preparation into their current plan of study (Worsham et al., 2013). Some science majors consider a career in science education, but ultimately decide against becoming a teacher; however, most science majors will never explore this option. While more work is needed in this area, it has been demonstrated that high achieving science majors (as measured by GPA and

science exam scores) are least likely to consider science teaching (Shugart & Hounshell, 1995; Moin et al., 2005).

A multitude of recruitment strategies have been proposed in the literature, although the efficacy of comparably few have been evaluated. The most widely supported recruitment strategy is providing science majors with science teaching experience (Borgerding, 2015; Saxman et al., 2010; Schuster, 2013; Tomanek & Cummings, 1999; Worsham et al., 2013). This strategy has been utilized by programs that have successfully recruited science majors into science teaching, including UTeach (Luft et al., 2005), T4 (Hubbard et al., 2015), CalTeach (Newton et al., 2010), CCSEP (Smith & Trexler, 2000), and MASS (Scott et al., 2006), and is further supported by research that demonstrates the relationship between teaching experience and interest in teaching careers (Dawson, 2007; Kilinç & Seymen, 2014; Wang, 2004). Financial incentives (in the form of stipends, scholarships, and tuition remission) are another widely utilized recruitment strategy; UTeach (Luft et al., 2005), CLUSTER (Saxman et al, 2010), MASS (Scott et al., 2006), T4 (Hubbard et al., 2015), and SMAART (Staudt et al., 2008) programs all provide financial incentives to recruits. However, there is limited evidence for the effectiveness of this strategy, and Bull et al. (1994) and Liou et al. (2010) disagree over whether financial incentives actually draw previously uninterested science majors into science teaching. Hoff and Lee (1986) provide evidence that a course devoted to providing science majors with information about a career in science teaching is an effective recruitment strategy, although this study utilized a small sample and is now quite outdated. Nonetheless, variations of this strategy may be found in successful science teacher preparation programs, including UTeach and MASS.

A review of the literature reveals that the existing research related to the development of interest in science teaching is sparse and often outdated. There is a need for research to resolve the issue of when potential science teaching candidates are most likely to form interest in science teaching, especially since the UTEACH model, which is spreading rapidly among U.S. schools of education, invests a great amount of resources into the recruitment of science majors early in their college careers (Luft et al., 2005). Such research should also address whether interest in teaching, science, or science teaching is likely to develop first. Many factors related to science teaching interest have been identified, but few have actually informed recruitment strategies. Research is needed to determine how teacher preparation programs can effectively identify and target science undergraduates with favorable dispositions towards science teaching (i.e., those who enjoy working with youth, are committed to social change, etc.); it should also identify how to target science undergraduates who are physical science majors, since existing recruitment efforts have been more successful at recruiting life science majors. A targeted approach may lead to recruitment that is more successful, more time and cost effective, and better able to meet the demand for qualified physical science teachers.

What do we know about science teacher retention?

We can also reduce the nationwide shortage of secondary science teachers by retaining existing highly qualified science teachers in the profession. Teachers leave the field due to retirement, family leave, and career changes (Ingersoll & Perda, 2009; Sutcher et al., 2019). Efforts to improve the retention of science teachers have focused on career changers, individuals who leave teaching to pursue other careers, as science teachers (along with mathematics teachers) are more likely than other teachers to leave the profession (Sutcher et

al., 2016) and to take non-classroom jobs in education (Ingersoll & May, 2012). Retirement has traditionally been viewed as a benign force since it typically occurred at the end of a long teaching career and was sufficiently balanced by new recruits into the profession (Ingersoll & Perda, 2009). However, health concerns and burn-out due to the current global COVID-19 pandemic have led to a wave of early retirement among teachers that further threatens the supply of highly qualified science teachers (Carver-Thomas et al., 2021; Zamarro et al., 2021). As the pandemic enters a third year, it may be necessary for researchers to reconsider the importance of retirement in preventing teacher attrition.

To improve science teacher retention, we must understand why teachers decide to leave the classroom. According to the literature, the most frequent reason teachers give for changing careers is low pay (Garcia & Weiss, 2019, Ingersol & May, 2012, Sutcher et al., 2016). Teacher salaries lag behind those of careers requiring similar education credentials (Garcia & Weiss, 2019; Sutcher et al., 2016); this pay gap is most acute for teachers working in high-poverty schools (Garcia & Weiss, 2019) and for mathematics and science teachers (Sutcher et al. 2016). Teachers also leave the field due to frustration with factors related to school environment, such as discipline problems, lack of parental involvement, and facilities (Garcia & Weiss, 2019; Carver-Thomas & Darling-Hammond, 2017; Ingersoll & May, 2012). These negative school environment factors are more likely to occur in high-poverty schools (Garcia & Weiss, 2019) and have been demonstrated to specifically impact the turnover of science teachers (Ingersoll and May, 2012). Lack of support from school leadership is another commonly cited reason for teacher attrition (Carver-Thomas & Darling-Hammond, 2017; Sutcher et al., 2019) – Viadero (2018) found that leadership plays an even more important role

than salary in teacher retention. Additional teacher characteristics have been associated with likelihood of attrition, including weak pedagogical preparation (Ingersoll, Merrill, & May, 2014; Sutcher et al., 2016) and weak commitment to teaching (Coladarci, 1992; Day et al., 2005; Torres, 2012).

Research into the causes of teacher attrition have led to an abundance of suggestions and strategies to promote teacher retention. The most obvious strategy to combat teacher turnover, increasing teacher salary (Carver-Thomas & Darling-Hammond, 2017; Ingersoll & Perda, 2009; Sutcher et al., 2016), is also the most difficult to enact. Instead, some researchers recommend targeting pay increases to schools and subject areas most likely to be impacted by teacher shortages (Garcia & Weiss, 2019) or more equitably distributing salary budgets across school systems (Carver-Thomas & Darling-Hammond, 2017; Sutcher et al., 2019). Given the impact of negative school environment on teacher attrition, many suggested strategies seek to equip teachers with the skills to create positive environments in their classrooms; these include mentoring and induction programs for early career teachers (Carver-Thomas & Darling-Hammond, 2017; Ingersoll & Perda, 2009; Sutcher et al., 2016) and high-quality professional development for teachers through their careers (Garcia & Weiss, 2019; Ingersoll & May, 2012). Suggestions to improve school leadership focus on strengthening principals (Sutcher et al., 2016; Ingersoll & Perda, 2009); Carver-Thomas and Darling-Hammond (2017) specifically recommend the development of accreditation standards for principal training programs that are informed by the research on teacher retention. While all of the previously mentioned strategies focus on in-service teachers, Ingersoll, Merrill, and May (2014) suggest that we can safeguard against attrition by ensuring that "that new teachers have received basic pedagogical

preparation" (p. 30), suggesting that teacher preparation programs can play a role in teacher retention.

Although the literature on teacher retention is robust, there is a need for research that examines not just why science teachers leave the classroom, but when they begin to consider leaving teaching so that we can best target retention strategies. Perda (2013) found that 42 percent of teachers leave the field in their first five years of teaching, while Ingersoll and Merrill (2013) found that early career teacher attrition has increased significantly since the 1990's. If an increasing number of teachers are leaving the profession at the beginning of their careers, we must consider that they enter the classroom lacking commitment to teaching. Finally, given that commitment to teaching is a construct closely related to teacher retention (Coladarci, 1992; Day et al., 2005; Torres, 2012), it has been poorly characterized among teachers in the United States; there is a need for research that explores the origins of commitment, as well as how to maintain and strengthen it.

Chapter 2: Context and Structure of Dissertation

Context

The University of Maryland's College of Education offers preservice secondary science teachers three pathways to certification: an undergraduate dual degree program, a five-year integrated master's certification program (IMCP), and a Master of Education with certification (MCERT) program. In the undergraduate program, students pursue dual majors in science and education, ultimately earning two bachelor's degrees. These students begin college as science majors and decide to become science teachers by midway through their junior year, when they must apply for admission to the College of Education to complete the requirements for a Bachelor of Science in Education and for teacher certification. In the IMCP pathway, students are awarded both a Bachelor of Science in their science content area and a Master of Education. These students apply to the IMCP pathway during their junior (and rarely, senior) years. They receive a Bachelor of Science in their science content at the end of their senior year, and a Master of Education and teacher certification in secondary science at the end of the fifth year. In the MCERT program, students who have previously earned a bachelor's degree in a science content area obtain a Master of Education and secondary science teacher certification in an accelerated one-year program.

Preservice science teachers in the undergraduate and IMCP programs at the University of Maryland are eligible to apply for the University of Maryland Noyce Scholars Program. Designed to encourage high-achieving science, mathematics, and computer science majors to consider careers in teaching, the scholarship provides its scholars with up to two years of funding in exchange for a commitment to teach in a high-needs school district for two years per

year of funding upon receiving teacher certification. In addition to the $14,000 per year scholarship, Noyce scholars participate in monthly seminars on relevant education topics and receive induction support.

My research was conducted at the University of Maryland (UMD), where I am a doctoral candidate in science education. The two papers that comprise this related-paper set include analyses of data collected from a cohort of six preservice science teachers during the 2014-15, 2015-16, and 2016-17 academic years. I first met these preservice science teachers, who were also all undergraduate science majors at UMD, in the fall of 2014 when I was the teaching assistant for their initial science teaching methods course, known at UMD as EDCI 411. As I described in my personal statement, I was concurrently exploring the recruitment of science majors into science teaching in other graduate assistantships and decided to take advantage of my access to these science majors to further develop this research. I applied for and received IRB approval to survey and interview students from the methods course regarding their experiences in science education and their interest in science teaching. I passed out and collected consent forms during our last EDCI 411 class but did not review the forms until after grading closed so that the students had no fear of reprisal for not participating. I received consent from all the science majors who intended to apply to the College of Education for admission into our science teacher preparation program; they will be referred to as my cohort throughout this dissertation.

I surveyed and interviewed my cohort in early 2015, at which point they had applied for admission into the College of Education but were still awaiting acceptance. All were subsequently admitted into the College of Education's science teacher preparation programs.

Of the preservice science teachers in my cohort, four obtained secondary science teacher certification through the undergraduate program, while two obtained certification through the IMCP pathway. Three participants became Noyce scholars. All the members of my cohort earned a Bachelor of Science in Biology or Chemistry and decided to pursue certification in secondary science education by the midpoint of their junior year at UMD. I interviewed my cohort again immediately before their graduation from the program and their certification as secondary science teachers.

Structure of Dissertation

In addition to my Personal Statement, Introduction, and Context and Structure of Dissertation chapters, this dissertation consists of two related papers (Chapters Three and Four) and a synthesis (Chapter Five). I have not included a traditional separate methodology chapter because each paper includes its own methodology. I was first encouraged to follow a related papers set format by committee member Dan Levin, during a conversation about my research interests and the data I have collected and analyzed. After discussing the format with Diane Jass Ketelhut, and confirming that the department's guidelines do not place any limits on dissertation format or structure, we decided that a related-paper set consisting of two papers would be the best way to present my research because all of the data that would contribute to my dissertation had already been collected and much of it had already been analyzed.

Chapter Three consists of a paper titled, ""Maybe I Should Try Out Becoming a Teacher": Why Science Majors Enter Science Teaching". As I discussed in my personal statement, this paper began as a conference paper that I presented at the 2016 NARST conference. After the positive reception of my work at NARST, I developed the conference

paper into a manuscript that I submitted to the Interdisciplinary Journal of Environmental and Science Education (IJESE). Following minor revision, this manuscript was accepted for publication on February 14th, 2020. In this chapter, I identify the factors that motivated the members of my cohort, six undergraduate science majors, to become science teachers and evaluate whether these factors have been described by the literature on science teacher recruitment. I find that the literature on science teacher recruitment describes many, but not all, of their motivations for becoming science teachers. I identify four novel motives: the influence of negative examples, the desire to enter workforce quickly, identity, and sense of community. These factors should inform both research into science teacher recruitment and the recruitment strategies employed by science education programs.

Chapter Four consists of a manuscript titled, ""What Will I be Like in a Few Years?" Teaching Commitment in Pre-service Science Teachers". In this manuscript, I explored the impact of a science teacher preparation program on its students' commitment to the science teaching profession. I found that my participants' commitments to science teaching changed over the course of their science teacher preparation program, and that these changes were attributable to elements of their program, including their coursework and student teaching internship. Given the connection between teaching commitment and retention in the teaching profession, I suggest that science teacher preparation programs may be able to impact their graduates' future retention in teaching by working to strengthen their commitment to science teaching. I plan to submit this manuscript to the Journal of Science Teacher Education.

Chapter Five is a synthesis chapter in which I review the main findings of each paper and draw upon them to provide further support for my assertions that the precursors of science

teacher attrition arise prior to science teachers' entry into the profession and for the role of identity in science teacher recruitment via its role in the conversion of interest in science teaching to commitment to science teaching. I also present a model representing the relationship between science teacher recruitment and retention and describe this relationship and how it is mediated by the conversion of interest in science teaching to commitment to science teaching. Finally, I discuss the implications of my research and suggest areas for future research.

Chapter 3: "Maybe I Should Try Out Becoming a Teacher": Why Science Majors Enter Science Teaching

Students, particularly those who attend public schools in low income, high minority areas, are increasingly likely to have out-of-field teachers for science (Cross, 2017; Kahle & Kronebusch, 2003; Moin et al., 2005; Sutcher et al., 2016). This shortage of in-field secondary science teachers is due in part to the inability of teacher preparation programs to recruit science majors into science teaching (Ingersoll & May, 2012; Moin et al., 2005; Wilson et al., 2004). To increase the number of recruits into initial science teacher preparation programs, schools of education must have access to research that explicates successful strategies for identifying and recruiting science majors; however, research in this area is sparse (Allen, 2005; Luft et al., 2011). Still, a review of the literature related to the recruitment of science majors into science teaching does reveal insights into how career interest in science teaching forms, which factors contribute to the development of interest in science teaching, and what strategies are likely to be effective to recruit science majors into science teaching, although it also reveals that existing studies include primarily white, female participants and have relied almost exclusively on the use of surveys. In this multiple-case study, I use a content analysis approach to reveal the factors that motivated six diverse undergraduate science majors to enter a science teacher preparation program. These factors were compared to those identified in the literature on science teacher recruitment. This analysis reveals that the literature has not adequately identified the reasons why a group of science majors decided to pursue science teaching. These six science majors' decisions to enter teaching were motivated by four novel factors: the professions' alignment to their identities and values, the sense of community found

in their college of education, a desire to enter the workforce quickly, and the negative example of prior teachers.

Literature Review

If the nationwide shortage of qualified secondary science teachers is to be reduced, schools of education must recruit more undergraduate science majors into science teacher preparation programs. To accomplish this goal, those administering science teacher preparation programs must have access to research that empirically demonstrates the best practices and policies for recruiting undergraduate science majors. Unfortunately, Luft et al. (2011) found that existing research on science teacher recruitment is sparse and generally limited to (a) reviews of existing, largely outdated, research on recruitment, (b) descriptions of existing science teacher recruitment programs, or (c) studies on teacher persistence. They concluded that:

> If we consider recruitment to be the initial step in the science teacher education process, then there is a… great need for studies that follow the decision-making process of potential teachers, that explore how the recruitment process impacts one's experience in a preservice program (p. 472-3).

Nevertheless, existing literature does offer some insight into what factors are likely to impact potential recruits' interest in science teaching and how those factors can inform recruitment strategies to introduce science majors to science teacher preparation programs.

A wide range of factors motivates the decision to pursue secondary science teaching. Pre-service and in-service science teachers most frequently cite their affinity for science (Bull et al., 1994; Dawson, 2007; Dominguez et al., 2015; Eick, 2002; Espinet et al., 1992; Kilinç &

Seymen, 2014) and desire to make a positive social impact (Bull et al., 1994; Dawson, 2007; Dominguez et al., 2015; Eick, 2002; Kilinç & Seymen, 2014) as the reasons why they entered the field of science education. Additional motivations for entering science teaching include a desire to work with youth (Bull et al., 1994; Dawson, 2007; Espinet et al., 1992; Kilinç & Seymen, 2014, Westerlund et al., 2011), positive prior teaching experience (Dawson, 2007; Kilinç & Seymen, 2014; Luft et al., 2005; Wang, 2004), positive impact by a former teacher (Dawson, 2007; Tomanek & Cummings, 1999), valuing the teaching profession (Dawson, 2007; Dominguez et al., 2015; Espinet et al., 1992; Kilinç & Seymen, 2014), and an opportunity to engage with science (Eick, 2002; Tomanek & Cummings, 1999). Although not cited as a motivating factor in studies of U.S. pre- and in-service science teachers, studies of science teacher recruitment conducted internationally have also identified job conditions (such as salary, demand, and workload) as having a positive impact on students' decision to pursue science teaching (Dawson, 2007; Dominguez et al., 2015; Kilinç & Seymen, 2014; Wang, 2004). Low teaching salaries, classroom management concerns (Evans, 1987; Worsham et al., 2013), discouragement from family and friends (Evans, 1987), and difficulty incorporating teacher preparation into their current plan of study (Worsham et al., 2013) have been identified as reasons why undergraduate science majors interested in science education do not become teachers. While some science majors consider a career in science education, but ultimately decide against becoming a teacher, most science majors will never explore this option. Specifically, high achieving science majors (as measured by GPA and science exam scores) are least likely to consider science teaching (Shugart & Hounshell, 1995; Moin et al., 2005) as a career option.

A multitude of recruitment strategies, seeking either to identify science majors with nascent interest in science teaching or to inspire such interest in science majors who would never otherwise consider science teaching, have been recommended in the literature, although the efficacy of only a few have been evaluated. The most widely supported recruitment strategy is providing science majors with science teaching experience (Borgerding, 2015; Saxman et al., 2010; Schuster, 2013; Tomanek & Cummings, 1999; Worsham et al., 2013). Financial incentives (in the form of stipends, scholarships, and tuition remission) are another widely utilized recruitment strategy. However, there is limited evidence for the effectiveness of this strategy, as Bull et al. (1994) and Liou et al. (2010) disagree over whether financial incentives draw previously uninterested science majors into science teaching. Hoff and Lee (1986) provide evidence that a course devoted to providing science majors with information about a career in science teaching is an effective recruitment strategy, although this study utilized a small sample and is outdated.

This multiple-case study was conducted to evaluate whether the literature on science teacher recruitment is sufficiently robust to encompass all the reasons for why a group of six undergraduate science majors decided to pursue science teaching. Specifically, I will answer the following question: What factors motivated six undergraduate science majors to enter a science teacher preparation program, and have all of these factors been described in the literature on science teacher recruitment? This analysis reveals that the literature has not identified all the reasons why a group of science majors decided to pursue science teaching. Four novel motives (those provided by participants but not described in the literature) are identified which should inform future research into science teacher recruitment.

Methods

Participants

This study took place in the College of Education (COE) at a public research university of approximately 40,000 students located within the greater metropolitan area of a major US city (referred to hereafter as "the University"). I used purposive sampling to identify the students in an introductory science teaching methods course who planned to apply to the University's secondary science teaching program. At the University, this course satisfies a general education requirement and does not require students to have shown prior interest in or commitment to teaching. Not all students enrolled in the course go on to pursue science teaching, and those who do may opt to apply to programs in either secondary science or middle school math and science. In the semester this study was conducted, fourteen of the twenty-four students in the course planned to pursue science teaching at the University. All seven students who indicated an intention to apply to the secondary science program consented to participate in this project, however, one student did not reply to requests to schedule an interview. Self-reported background information for the remaining six participants is summarized in Table 1 (pseudonyms have been used).

Table 1

Self-reported background information

	Science major	Racial/ethnic background	Academic year	Education program applied to
Eric	Biology	White & Native American	3rd year/Junior	Five-year integrated master's degree with certification
Bryan	Biology	White	3rd year/Junior	Four-year double major in science and secondary science education with certification
Sarah	Biology	Indian	3rd year/Junior	Four-year double major in science and secondary science education with certification
Alice	Biology	Chinese-American	3rd year/Junior	Four-year double major in science and secondary science education with certification
James	Chemistry	Asian-American	3rd year/Junior	Four-year double major in science and secondary science education with certification
Tom	Biology	White	4th year/Junior	Five-year integrated master's degree with certification

Data Collection

To learn more about why undergraduate science majors decide to enter a science teacher preparation program, I interviewed participants following the completion of their introductory science teaching methods course. I conducted interviews using a semi-structured interview protocol containing 30 to 40 items that were individualized to each participant based on their responses to an 18 item online pre-interview survey. Both the online survey and the interview protocols were informed by the literature on pre-service science teacher recruitment.

Interviews were audio recorded. No notes or artifacts were collected from the interviews, although I wrote analytic memos following the conclusion of each interview. I used InqScribe digital media transcription software to transcribe audio-recordings of the interviews.

Literature Review

I conducted an exhaustive review of the literature on secondary science education recruitment utilizing Creswell's (2002) five-step approach. The literature review yielded both studies describing how career interests in science teaching form and studies offering recommendations for recruiting science majors into initial science teacher certification programs. The results of these studies served as a source of deductive codes.

Data Analysis

To determine whether the current literature on science teacher recruitment has captured all the reasons why a group of prospective pre-service science teachers decided upon a career in science education, it was necessary to develop a rich understanding of why each student decided to pursue science teaching. I determined that this goal would be best accomplished via a qualitative research methodology. I chose to construct a multi-case study using a directed qualitative content analysis approach. In this analysis, each participant's experiences in and reasons for choosing to pursue science teaching represent a unique case, as I expected no two participants to have followed the same pathway from science major to prospective science educator. Multiple cases were used to increase the likelihood that I would identify novel motives for pursuing science teaching, and to evaluate the degree to which individual students' pathways were or were not similar.

Qualitative content analysis can be defined as "a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns" (Hsieh & Shannon, 2005). As a research method, one of its primary affordances is flexibility, as analysis may be conducted via an inductive or deductive approach (Elo & Kyngäs, 2008). Further, it can be used to describe both novel or uncharacterized phenomena and incompletely analyzed or characterized phenomena. I chose qualitative content analysis due to this flexibility, as I knew the use of both inductive and deductive coding would be necessary to answer my research question. I consider this qualitative content analysis to be directed (Hsieh & Shannon, 2005) because it was informed by existing, potentially incomplete research findings regarding science teacher recruitment.

To accomplish my goal of identifying novel motives for pursuing science teaching, two rounds of coding were done. In the first round, I coded all transcripts inductively, using an open coding method. Portions of the transcripts dealing with (1) what factors impacted participants' interest in science teaching, and (2) participants' knowledge of or experience with recruitment strategies were highlighted and given descriptive codes. I then reviewed these descriptive codes and collapsed similar codes into categories. To assess the reliability of the inductive coding scheme and minimize subjectivity, my process of category development was responsive to criticism and feedback. During the year I spent transcribing, coding, and analyzing interview data from this study, I participated in a weekly research seminar with fellow science education graduate students and faculty. At these meetings, I shared my inductive coding scheme and subsequent emerging categories along with supporting evidence from participant interview transcripts. My categories were refined and modified in response to feedback from my

colleagues. Using this method, I ensured that my inductive coding scheme was both transparent and systematic, characteristics identified as essential for rigorous qualitative research (Meyrick, 2006).

A second round of coding utilized deductive coding. I selected deductive codes after conducting a review of the literature on recruiting science majors into secondary science teaching programs (see Table 2). To minimize potential researcher bias and reduce coding errors, the reliability of the deductive coding scheme was assessed using two pilot interviews. Three pages of interview transcript, comprising greater than 10 percent of the total pilot transcript data (Campbell et al., 2013; Hodson, 1999) were reviewed and coded by myself and two other graduate assistants. There was greater than 90 percent agreement between each pair of coders, demonstrating high intercoder reliability (Neuendorf, 2016); further, through negotiated agreement (Campbell et al., 2013), we were able to resolve the discrepancies between our coding, ensuring a high degree of both intercoder reliability and agreement.

I reviewed coded transcripts and used them to construct a case for each participant. Those cases are presented as narrative profiles in the next section. Profiles were constructed with a focus on the factors that impacted participants' interest in science teaching and participants' knowledge of or experience with recruitment strategies.

Table 2

Deductive codes derived from the literature

Coding category	Specific code	Reference

Reasons science undergraduates consider science teaching	1. Affinity for science	Bull et al., 1994; Dawson, 2007; Dominguez et al., 2015; Eick, 2002; Espinet et al., 1992; Kilinç & Seymen, 2014
	2. Positive social impact	Bull et al., 1994; Dawson, 2007; Dominguez et al., 2015; Eick, 2002; Kilinç & Seymen, 2014
	3. To work with youth	Bull et al., 1994; Dawson, 2007; Espinet et al., 1992; Kilinç & Seymen, 2014, Westerlund et al., 2011
	4. Positive prior teaching experience	Dawson, 2007; Kilinç & Seymen, 2014; Luft et al., 2005; Wang, 2004
	5. Positive impact by a former teacher	Dawson, 2007; Tomanek & Cummings, 1999
	6. Valuing the teaching profession	Dawson, 2007; Dominguez et al., 2015; Espinet et al., 1992; Kilinç & Seymen, 2014
	7. Opportunity to engage with science	Eick, 2002; Tomanek & Cummings, 1999
	8. Job conditions (i.e. salary, demand, & workload)	Dawson, 2007; Dominguez et al., 2015; Kilinç & Seymen, 2014; Wang, 2004
	9. Recruitment	
	a. Science teaching experiences	Borgerding, 2015; Saxman et al., 2010; Schuster, 2013; Tomanek & Cummings, 1999; Worsham et al., 2013
	b. Financial incentives	Liou et al., 2010
	c. Introduction to science teaching careers course	Hoff & Lee, 1986
Reasons science undergraduates do not consider science teaching	10. Low salary	Evans, 1987; Worsham et al., 2013
	11. Classroom management concerns	Evans, 1987; Worsham et al., 2013
	12. Discouragement from family & friends	Evans, 1987
	13. Difficulty incorporating teacher preparation into current plan of study	Worsham et al., 2013
	14. High achievement in science	Moin et al., 2005; Shugart & Hounshell, 1995

To determine whether the literature has adequately identified all the reasons why participants decided to pursue science teaching, I compared categories arising from open coding to the deductive codes generated from the literature. Any open coding categories that lacked a homologous deductive code represented a novel motive for the pursuit of science

teaching. Further, any deductive code not found in the transcripts represented a previously identified motive that did not play a role in these participants' career decisions. Any discrepancies between the literature and the experiences of the six participants are summarized in the Discussion section.

Results

Eric

Eric's interest in teaching developed in high school. He considered teaching English or science, as those were his favorite subjects. Eric explained that teaching interested him because:

> I've just seen really good teachers and apathetic teachers, and just realizing the potential, of having a positive influence on people, that's what really motivated me to want to become a teacher… seeing the different types of teachers, that made me really want to be a teacher.

He chose science teaching over English teaching because of a combination of his interest and ability in science, explaining, "I really like science and I like to visualize it, and I feel like it's a good way to learn it, so I feel like I would be a decent science teacher." In high school, Eric also considered a career in science research, which led him to apply to the University as a biology major. His mother encouraged this interest by helping him get a summer research internship at the FDA, where she works as a researcher. This internship, which took place in the summer between high school and college, convinced Eric that research was not for him. He shared that "from day one [of college] I knew that I was going to be an education major. So, I attended the first change of major workshop that I could to get into education."

Since entering college, Eric's decision to pursue science teaching has been affirmed by several experiences. He has worked as a teaching assistant, which has given him practice in planning and differentiating lessons to different types of students. He has worked with elementary and secondary students through volunteer opportunities and as a Noyce scholar, and has realized that he has an affinity for young people, stating that "I just feel more free to be myself in front of kids than adults." Teaching experiences from the Noyce program have also given Eric "the opportunity to see if this is what I'm meant to do, and it was. It was very affirming." Eric has also recognized a disconnect between himself and the pre-med students who dominate the biology major:

> I came into it [college] thinking I was a science education person. I don't really like the types of people who are science pre-meds, because they're stuck up in their life, their future life, and the monotony that it is. And they're very focused on being successful. I, too, would like to be successful, but it's a different type of thing. The education type of people, the humanities type of people are more open-minded and empathetic… they're [biology majors] going for grad school and medical school and it's very competitive.

The value given to empathy in education is important for Eric, who shared that, "I like helping people more than I like helping myself. It makes me happy." Eric was unaware of any recruiting efforts being made by the COE aside from the Robert Noyce Teacher Scholarship Program, a nationwide, National Science Foundation funded program in which the University participates that provides scholarships to science majors pursuing science education. While Eric is a Noyce scholar, he joined the program after deciding to teach, so it did not impact his choice to pursue teaching.

Eric has been discouraged from pursuing teaching by his friends because of teachers' income potential. While Eric identified salary as a negative of teaching, he was unconcerned because teaching is "fulfilling and rewarding in ways besides money." Eric was critical of the advising he has received from the COE and has had difficulty in getting correct information about which courses are required for the teacher preparation program. He says he has only been able to "figure it out through repeatedly going to advising" and says that friends have shared similar frustrations.

Bryan

Bryan first considered science teaching during his freshman year at the University. In high school, he considered a career in either science or history, as those were his two favorite subjects. He explains:

> What made me decide that I wanted to go into science, because I really like history, too, was the job market. I knew that in history you don't really get a job, you know, science is highly needed with STEM and stuff like that.

When he entered college, he planned to become a doctor, but shared that he began questioning this decision because:

> I started realizing that I don't think I wanted to spend my 20's in school or go to the route where I would not be able to work with people other than having patients, because I really like working with people, especially younger people.

Bryan was given a work-study position in the COE during his freshman year. While he believes that he would have eventually come to teaching without this position, he acknowledges that it did have an influence on his decision, as it came during a time when he

"was starting to think about other options." Bryan decided to become a science teacher by the beginning of his sophomore year.

Bryan recognizes that his decision to become a teacher was influenced by prior teaching experiences. His first "practice in teaching" came from tutoring in chemistry and physics during high school. In college, he gained more experience teaching lifeguarding classes, which included science concepts such as the "cardiac cycle," and realized that he "really enjoyed standing up in front of people and teaching… I started liking the idea of instead of being selfish with my knowledge, being able to provide it to everyone else, too." Bryan's decision was also motivated by the possibility of impacting the quality of science education in rural areas; he felt that his rural science education left him ill-prepared for the rigors of college science courses, although he did acknowledge that his best teacher was his high school chemistry teacher. He believes that "the best way to fight back against a system that might be going bad is to get in it and do it the right way and support the right ways to teach". Bryan has received encouragement from people in his hometown, who hope that he will return to the community to teach science. Bryan also shared a desire to work with people, especially young people because, "they are so excited all the time, and it's neat to make them happy." Bryan looks forward to the job conditions of teaching, sharing:

> I like how the teachers work together, and the sense of camaraderie among coworkers that you wouldn't get if you had a job where you didn't really work with other people trying to achieve the same goal. The hours are nice, the benefits are great, and if I ever wanted to have a family, it's perfect, too, to have summers off.

While Bryan recognizes that teachers' salary may be off-putting for many of his science major peers, especially physics and chemistry majors who "could get a six-figure salary," it was not a concern for him, because he's "not a big spender" and comes "from a family that's not rich". He did receive discouragement from his grandmother, a retired English teacher: "My grandmother doesn't really support people who want to become teachers because she thinks the system is getting bad. She's not a fan of common core and she doesn't like how it's all about tests now," but she was unable to dissuade Bryan from pursuing teaching.

Sarah

Sarah decided to become a science teacher because of her experiences during the introductory science teaching methods course. Sarah was interested in science from an early age, and first remembers deciding upon a career in science at age 13. By high school, she decided that she wanted to be a doctor, although she explains that

> I'd always thought of teaching when I was in high school. I always really liked teaching, but I just never really pictured myself as being a teacher… I always liked teaching, I just never saw it as, this is what I'm going to do.

This interest may have been influenced by her high school science teachers, who were "really great teachers… they really liked the subject they were teaching; you could tell that they weren't just there to do their job." During high school, Sarah also began what has become a yearly summer internship at a biomedical research facility. Although Sarah entered the University intending to become a doctor, the influence of her summer internship experience led her to instead plan for a career in biological research.

While still intending to become a researcher, Sarah realized that she had enough free credits to earn a minor. At the same time, Sarah's interest in teaching was revived by a positive experience working as a teaching assistant. Knowing Sarah's interest in education, her sister suggested that she add a minor in education. After speaking to her advisor, Sarah decided to add a second major in secondary science education, although she still planned for a career in research. Sarah explains that:

> After I decided to double major in education, I started to see it as a more realistic option, as opposed to just a backup plan. That was when I realized that I actually did enjoy the possibility of being a teacher.

Sarah decided that she wanted to work as a science teacher because of an internship in a local high school that was a requirement of the introductory science teaching methods course. Her change in career aspiration was inspired by observing teachers, which she identified as falling into two categories, those who could motivate struggling students to do better, and those who just wanted struggling students not to disrupt their class, saying that:

> When I saw that, it made me want to change that and to be that teacher who pushes students to do better, to not just be like okay, just sit in the back of the class and don't disrupt people.

Sarah believes that teachers do not receive the financial compensation that they deserve but says that "I've accepted that I'm not going to get the most fabulous pay, but I'm okay with that considering that I've chosen this, so I'm not going to complain about it." She has been discouraged from pursuing teaching by her friends and family because of the profession's salary and perceived low prestige; she shared that her father "was surprised because he felt like

I could do more than just teach, like I was settling for being a teacher." While she understands their concerns, she is pushed to continue to pursue science teaching because she enjoys teaching.

Alice

Alice first considered science teaching during her sophomore year of college. Alice comes from a family that highly values science - both of her parents are scientists, and her brother is in medical school – so she always expected to work in science. She decided to become a pediatrician after taking anatomy in 11th grade, since it would allow her to combine her interest in the human body and "working with kids." Alice's father convinced her to enter the University as a bioengineering major, but Alice struggled with the major's physics and mathematics requirements. She explained:

> I decided I can't really do this engineering thing, all this physics in it is not really my thing. Math has always been hard for me. So, I decided not to do bioengineering. I decided to change to just bio.

Initially, she still intended to become a doctor, but realized that she "didn't want that stressful pre-med life anymore" and that it would be difficult for her to raise her GPA to a level competitive with her pre-med peers. At that point, Alice shared:

> I think I realized, because I knew I wanted to work with kids and I liked working with kids, there were other ways to help people than just being a doctor who works with kids. And I was like maybe I'll try out education.

Alice ideally would have chosen elementary education, but was discouraged by her father, who said "you can't just do elementary education" and because she felt like she would

be wasting all the biology credits she had already earned, so she decided to enter the secondary science program.

Alice's decision was impacted by several volunteer experiences, including tutoring, camp counselling, and an afterschool math and science program. She participated in these programs because they gave her an opportunity to work with children, but she says they also gave her "an opportunity to see what it would be like to actually teach kids in a subject area." Alice is also motivated by the possibility "to work in the urban areas and help people who have much more need than where I came from." She also identified job security as a benefit of the teaching profession, saying that "people will always need teachers." While Alice was not initially encouraged to pursue teaching by her friends and family, she said that "a lot of people now are affirming me for being in science education, a lot of them are like, oh, I can imagine you as a teacher or you'd be a great teacher."

Alice identified salary as a con of teaching but says that "I think it discouraged my dad more than me. I'm not too worried about it." She hopes to teach in an urban area but expressed concern over the emotional toll of ongoing classroom management issues. Although Alice's father was initially disappointed and discouraged her from pursuing science teaching, he has accepted her decision because it does not require her to abandon a degree in science, which he views as a backup plan in case she does not like teaching.

James

James never seriously entertained any career options other than science teaching. He shared:

> I always sort of knew in the back of my mind that I had a gift of teaching, meaning that whenever I am teaching, or whenever I am translating information, or whenever I am just guiding someone to learn something, I'm particularly good at it compared to my peers. I always noticed that in high school, so that's when I thought of becoming a teacher.

In high school, James' parents encouraged him to explore other career options that they viewed as being more prestigious:

> I don't know if you know, but traditional Asian parents, they want you to be a doctor… a lot of parents have the dream of, since I didn't do well, I want my sons and daughters to do well, so my parents had the idea of why don't you become a doctor. So, I thought of pharmacist, because it has to do with chemistry. I gave it a thought, of being a doctor.

By the start of his freshman year, James had decided to become a science teacher. He explained that the decision was the result of "a gradual acceptance" of himself and struck a balance between "all the things that I've been through, all the things that I want to do, and what I'm good at."

James' decision to pursue science teaching was inspired and facilitated by former teachers. As an English language learner, James struggled in his eighth-grade English class, but explains:

> My teacher really didn't ever give up on me… that was when I sort of defined a good teacher as a teacher who really pays attention, who really gives attention to his or her students. Who really likes, not only teaching, but students. That was when I thought

> maybe teaching is one thing that I really want to do, to really help those who were in my situation, who didn't really like learning,

James developed a close friendship with his Advanced Placement chemistry teacher, who was a graduate of the University's science teacher preparation program and encouraged him to become a teacher. James also acknowledges the impact that tutoring has had on his career plans, sharing that "tutoring is actually a big part of my life;" he has tutored continually since 10th grade. Like Eric, James is a Noyce scholar, but he also joined Noyce after committing to teach. Tutoring, education internships, and the Noyce program have served to develop and affirm his decision to teach science.

James believes that some teachers are inadequately compensated for their work but is not discouraged by salary expectations. Although his parents were initially disappointed by his decision to become a science teacher, he shared that "now they're really supportive of my decision." He expressed some concern over classroom management issues, which may lead him to teach in a suburban, rather than urban, school district.

Tom

In high school, Tom briefly considered a career in medicine or law, but decided to become a math teacher due to his aptitude in math and desire to help people. He shared:

> I always liked helping people… it is very rewarding to help people. I know what it's like to be helped, and I want to help people's lives be easier with school. I've had a lot of negative experiences with it, and I don't think it needs to be that negative. You can enjoy learning, and you're in school for so long you *should* enjoy it.

Tom entered the University intending to double major in mathematics and secondary education, but quickly realized that he "didn't want to do math anymore." A positive experience in his freshman biology course led him to switch majors to biology; he explained:

> I started liking science, so I dropped education and thought about pursuing a science field, biology. I was thinking about being a nurse or a PA… I never like stopped liking teaching, but I didn't want to be a math teacher.

Tom quickly realized that he did not want to become a health professional, due to the length of school required, so he reconsidered teaching. He explained,

> I found out that I like biology, it's kind of hard, but I also like teaching, and it just kind of worked out so my junior year I decided to put the two together… Teaching is an incredibly rewarding job. And it matches up with me not wanting to be in school as a student for a very long time… Teaching has always kind of been my first goal, and then biology came secondly.

Tom attributes his interest in teaching in part to his family, sharing, "my family are also all teachers or principals… they definitely never pushed me, I don't think, but I just see them as they are, and I see they're happy and I see all of us doing well." Although Tom has not tutored formally, he has always helped his friends study, explaining "if they were struggling and I knew it was something I was good at, I always would jump on it before they even asked," and feels that these experiences influenced his decision to become a science teacher. He has worked with children of all ages and is drawn to working with young people because of the opportunity to create an environment where they can discover "who they are."

Tom has had difficulty incorporating the requirements of the University's science teacher preparation program into his academic plan. Since he changed his major from mathematics to biology and is now adding a second major in secondary education, he will need to stay at college for a fifth year. He also has had to defer application to the program to the spring to raise his GPA to that mandated by the program but can continue to take required education classes in the interim.

Discussion

I found that all the factors identified as positively contributing to the development of science teaching interest by the literature on science teacher recruitment played a role in some or all the participants' decisions to enter science teaching (Table 3). Consistent with the literature, all six participants expressed a strong affinity for science and viewed science teaching as a way to remain deeply engaged with science content, rather than as a means of distancing themselves from science. Also, consistent with the literature, all participants valued the teaching profession, expressing admiration and respect for the work of teachers and disdain for the current low status of teachers. All participants except Eric had gained teaching experience (although of varying formality and duration) via tutoring, teaching assistantships, and/or summer camp work prior to making the decision to pursue science teaching. All participants except James cited the opportunity to work with youth as a compelling reason to choose teaching; James shared that he did not have a specific desire to work with young people, but instead a more general desire to work with people that teaching fulfilled.

Table 3

Factors positively impacting science teaching interest, from literature

	Eric	Bryan	Sarah	Alice	James	Tom
Affinity for science	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Positive social impact	No	**Yes**	**Yes**	**Yes**	No	No
To work with youth	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**
Positive prior teaching experience	No	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Positive impact by a former teacher	No	No	**Yes**	No	**Yes**	No
Valuing the teaching profession	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Opportunity to engage with science	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Job conditions	No	**Yes**	No	**Yes**	No	**Yes**
Recruited?	No	No	No	No	No	No

Participants expressed mixed commitments to making a positive social impact. Sarah and Alice explicitly desired to effect change in urban areas and Bryan explicitly desired to effect change in rural areas, due to perceived deficits in the quality of science instruction in those areas. While other participants did not express social change to be a priority, all participants cited a more general desire to help people as a motivating factor in their decision to pursue teaching. For example, Tom shared, “I always liked helping people… it is very rewarding to help people.” Participants also differed in the role the influence of former teachers had in their

decision. Sarah and James had former teachers who inspired them to pursue science teaching, either indirectly through their contagious passion for the subject (Sarah) or directly through acting as a mentor (James). Far from being inspired by their former teachers, Eric, Bryan, and Tom criticized the quality of science instruction they received as secondary science students. For Bryan, Alice, and Tom, job conditions related to teaching, such as job security, work-life balance, and schedule, were also motivating factors in their decision.

No participants felt that they had been recruited into the science teacher preparation program by the COE; in fact, only two participants recalled being aware of any efforts to recruit science majors into the program. Eric and James were Noyce Scholars, a program that is intended to encourage science and mathematics undergraduates to explore teaching; however, Eric and James both applied for the scholarship after they had already decided to pursue teaching, so they were not recruited by the scholarship, even though they recognized that to be its intended purpose. All participants initiated their relationships with the COE; in some cases, this required perseverance, as some participants expressed frustration over their difficulty in obtaining reliable information about the program through advisors and the COE's website.

Even though my participants included only science majors who planned to pursue science teaching, I was interested to see if they shared any of the concerns of science majors who choose not to become science teachers that have been reported in the literature (Table 4). None of the six participants were concerned with science teacher salary expectations. While all participants identified pay as a con of the teaching profession, they were not personally concerned with their ability to live with a teacher's salary. Both female participants shared that low pay was particularly concerning to their parents, who encouraged them to pursue more

lucrative career paths. This parental concern was not shared by any of the male participants. Only Alice and James expressed concern over classroom management, and their concern was limited to urban classroom contexts. Tom was the only participant who was not discouraged from pursuing science teaching by his family, friends, or science classmates. Alice and James attributed their family's discouragement, in part, to their Asian-American backgrounds, claiming that in their families, teaching is not held to the same esteem as other science professions. Sarah discussed her father's reaction to her decision to teach, sharing that he was "kind of surprised because he felt that I could do more than just teach, it was like I was settling for being a teacher." Only Tom had difficulty incorporating teacher preparation requirements into his course of study, and this was due more to his earlier major change than to the demands of the education dual major. Contrary to findings by Moin et al. (2005), all six participants had GPA's of at least 3.0 (this is a pre-requisite for application to the University's science teaching program). The existing literature on science teacher recruitment has captured many of this group of undergraduate science majors' reasons for pursuing science teaching; however, the following motivations were not reported in the literature.

Table 4

Factors negatively impacting science teaching interest, from literature

	Eric	Bryan	Sarah	Alice	James	Tom
Low salary	No	No	No	No	No	No
Classroom management concerns	No	No	No	**Yes**	**Yes**	No
Discouragement from family & friends	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No
Difficulty incorporating teacher prep	No	No	No	No	No	Yes
High achievement in science (GPA ≥ 3.0, Moin et al., 2005)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes***

*Tom's GPA would be 3.0 at the time of application to the program

Influence of Negative Examples

While the literature has identified the positive impact of previous teachers as a factor that motivates interest in science teaching, Eric, James, and Tom's decisions to enter science teaching were motivated by negative experiences with teachers. Eric contrasted his English teacher, who "obviously didn't put in any work, didn't care to expand our knowledge… didn't go above and beyond the bare minimum" with his math teacher, who "was very good at explaining things and encouraging me… he expected success out of me," and explained:

> I've just seen really good teachers and apathetic teachers, and just realizing the potential, of having a positive influence on people, that's what really motivated me to want to become a teacher… seeing the different types of teachers, that made me really want to be a teacher.

James described how his chemistry teacher, “who didn’t really teach me effectively,” inspired him to consider teaching:

> [I thought] maybe if I became a teacher who actually teaches things and relates materials to real life situations, maybe I want to do that I realized. I think that was a moment when I sort of thought of becoming a teacher.

Tom explained that his science teachers demonstrated “more what not to do than what to do” as a teacher. These negative experiences influenced Tom to choose science teaching so that he could create positive learning experiences for his students.

Desire to Enter Workforce Quickly

The decisions of Bryan, Sarah, Alice, James, and Tom to enter science teaching were all motivated by a desire to begin a career quickly, rather than spend years in graduate or professional school, which they considered to be necessary for a career in science. Many also felt that this represented a disconnect between themselves and their science major peers, who they felt were looking forward to spending a long time in school. Bryan shared that most science majors:

> Seem to be dead set dedicated on spending a really long amount of time in school to become a doctor or what not. And I started realizing that I don’t think I want to spend my twenties in school… I like the idea of being able to finish my undergrad and have a job, so I’ll be honest with that part.

Tom shared similar priorities as he explained his decision to pursue teaching instead of a career in the medical profession:

> I'm trying to be done with school as quickly as possible, even if my grades were as high as they need to be for being a doctor, I definitely do not want to be pursuing that, I'm not interested in being in school that long… I didn't want to put in the time in school to get there. I was ready to move on as quickly as possible to being an independent person.

Since the University's science teacher preparation program can be completed alongside a science major within four years, a career in science teaching fulfilled the desire to being in the workforce as soon as possible.

Identity

Participants' decisions to pursue science teaching were the result of a process of self-discovery that consisted of (1) acknowledging their own interests, strengths, and values, or identity, and (2) recognizing that that identity makes them better suited for a career in science teaching than for other careers they considered. Participants progressed through this process at different rates, which is why they made the decision to teach science at different points in their education. I believe that positive prior teaching experience contributes so strongly to an interest in science teaching because it facilitates this process of self-discovery. This process is described by James:

> It was a gradual acceptance of myself as, I keep saying gifted, but I'm not saying that to promote myself in another way, but I'm just saying that I was just innately able to deliver information and make things more interesting than my peers and others, and an average person. So, I think that knowing about myself and having that just conscience of myself was one of the factors that really got me into teaching science, that was one of the factors. And all of these experiences I had up until now, internships, even

> volunteering work, these really were all the factors that got me into, that got me more into teaching because obviously the experiences I had were after I had made the decision to teach, of becoming a teacher. But I guess it wasn't a decision that I wanted to become a teacher, but maybe I should try out becoming a teacher and then as I was having these experiences, I was able to confirm myself and confirm my decision.

Some participants recognized that their identity made them better suited for a career in science teaching than for other science careers after realizing that their identity was not the same as, and was sometimes in direct conflict with, that of other science majors. With the exception of James, all participants were biology majors and were critical of their science major peers. These participants felt that their peers, who were primarily pre-med students, dictated the culture of the University's College of Computer, Mathematical, and Natural Sciences (CMNS), which they characterized as one of competition and stress. Bryan explained that starting college "was a bit of a shock, I was now a small fish in a big pond… the competition was really intense." Sarah explained that "it can be hard as a science student, because there's a lot more stress coming from the exams and just the competition that there is in the science field." Alice directly attributed her change in career plans to this culture, explaining that she "didn't want that stressful pre-med life anymore." Eric compared pre-med students to students in the COE:

> I don't really like the types of people who are science pre-meds because they're stuck up in their life, their future life, and the monotony that it is. And they're very focused on being successful. I, too, would like to be successful, but it's a different type of thing. The

> education type of people, the humanities type of people are more open-minded and empathetic.

The mismatch between participants' identities and those of other biology majors led participants to feel out of place and seek a career option that allowed them to combine their affinity for science with their desire for cooperation and helping others. Science teaching met that need and provided a caring community of faculty and peers with similar interests, strengths, and values. This is consistent with Luehmann's (2007) identity development framework, where she contends that "people approach learning situations with core identities in place that need to align with the new identity being considered" (p. 828). Participants' core identities did not align with a science identity as presented by the CMNS, but instead with the science teacher identity common in the COE. Further, the sense of community they found in the COE ensured that their science teacher identities were recognized and validated, which Luehmann considers an essential component of science teacher identity development.

Sense of community

All participants were critical of their experiences with professors in the CMNS at the University. Eric described his science professors:

> The instructors aren't as student focused, I would say. I think it's just more getting the content out in a timely manner. They aren't focused on the ease of student comprehension, that's not their problem, the students need to work on it. They're only worried about getting what the students need to know out.

Tom was less forgiving in describing science professors, saying:

> They're not very good. They read the PowerPoint for 50 minutes, give you reading assignments, and it's pretty much all on you… I don't really have a lot of good things to say about the science classes here.

James excused the quality of instruction in his science classes, because "college instructors aren't really required to have any interest or gift or *anything* that has to do with teaching." Alice described her science professors as "boring" and "distant," a sentiment shared by Bryan, who shared that his science classes were "too big to interact with your professors."

In contrast, participants praised the instruction they received in the COE. Sarah directly compared her experiences in the CMNS and COE:

> It almost feels like you're in different colleges when you're in different classes for education versus bio…as an education student, you have a one-on-one relationship with the teacher, so it feels a lot more like you're being guided through it.

Similarly, Alice shared: "I feel like teachers who teach about teaching are good at it… that's definitely been a nice change from my normal science classes." Bryan also compared his experiences, saying "the education classes I've had, I loved way more than my science classes… the atmosphere in the classes is just really positive," and saying that he has received "intense encouragement" from the COE. Eric explained that his experience in the COE has "made me spoiled with good teachers that I feel care about my opinion. That's what I really appreciate about my education classes, the individualized sort of thing." Sarah echoed this, saying that her experience in the COE has "felt a lot more personalized."

I believe that what participants are describing in their interactions with the COE is a sense of community. Sarason (1974) defines sense of community as "the sense that one was

part of a readily available, mutually supportive network of relationships upon which one could depend and as a result of which one did not experience sustained feelings of loneliness" and asserted that community is "one of the major bases for self-definition" (p. 157). Participants did not feel a sense of community in the CMNS. For participants who decided to become science teachers before college, this lack of community affirmed their self-definition, or identity, as future science teachers. For participants who decided to become science teachers during college, this lack of community motivated them to explore other career options, which brought them to the COE. Once in the COE, these participants found a sense of community, which facilitated the development of their identities as future science teachers.

Conclusions

To increase the number of recruits into initial science teacher preparation programs, schools of education must have access to research that explicates successful strategies for identifying and recruiting science majors. I conducted this analysis to evaluate claims made by Allen (2005), Luft et al. (2011), and others that the literature on the recruitment of science majors into science teaching is sparse, and unable to adequately explain why undergraduates decide to pursue science teaching. To do so, I interviewed six undergraduate science majors who have committed to an initial science teacher preparation program to ascertain their motivations for choosing a career in teaching. The literature on science teacher recruitment has identified many, but not all their reasons for becoming science teachers. In addition to commonly cited factors (i.e., an affinity for science, desire to make a positive social impact, etc.), these six science majors were also influenced to teach by the professions' alignment to

their identities and values, the sense of community fostered by the COE, a desire to enter the workforce quickly and the negative example of prior teachers.

I believe that the failure of the literature to capture the full range of reasons why science majors decide to enter science teaching can be attributed to several factors. First, existing studies have failed to incorporate diverse theoretical perspectives. Several studies have used career theories; however, most studies of initial science teacher recruitment are grounded in no theoretical perspective. Based on the findings of this analysis, future studies should draw upon identity and community psychology theories. Second, diverse methodologies and data sources are also needed. Many studies of teacher recruitment rely upon the use of survey instruments. While surveys can be useful, they are generally informed by previous research, and therefore have limited utility in identifying previously uncharacterized motivations, especially when the existing research they are based upon has been criticized as being sparse. Further, the use of survey instruments results in a list of isolated factors and does not allow researchers to identify the connections between these factors or to provide deeper, richer descriptions of how these factors play into undergraduates' decisions. Finally, if the goal of science teacher preparation programs is not just to increase the number of science teachers, but also the diversity of the corps of science teachers, then future studies designed to inform recruitment should include participants from diverse backgrounds. Most studies reviewed were primarily of white, female pre- and in-service science teachers; it is possible that the six undergraduates included in this study shared novel motives because they represent a more racially and ethnically diverse sample.

A limitation of this study is that it was conducted at a single university; therefore, findings may not be generalizable to students recruited into other teacher preparation programs. Similarly, the study focused on an undergraduate initial teacher certification program, so findings will not be generalizable to post-baccalaureate and/or alternate certification programs. Another potential limitation is the sample of undergraduate science majors interviewed, as they were ethnically diverse and mostly male, which is uncharacteristic of typical pre-service science teacher cohorts. As teaching assistant of the introductory science teaching methods course, my relationship to the participants may represent another limitation. Even though interviews were conducted after the conclusion of the course, it is possible that my affiliation with the University's College of Education impacted the candor of their responses. However, it is equally likely that my prior relationship with the participants encouraged them to reveal more about their backgrounds than they otherwise would have.

Chapter 4: "What Will I be Like in a Few Years?" Teaching Commitment in Pre-service Science Teachers

High schools across the United States struggle to find qualified science teachers to staff their classrooms (Cross, 2017; Martin & Mulvihill, 2016), a situation further exacerbated by the COVID-19 pandemic (Carver-Thomas et al., 2021; Zamarro et al., 2021). This science teacher shortage results from a combination of low levels of recruitment into the profession and high levels of attrition from the profession (Ingersoll & May, 2012; Sutcher et al., 2019). We can expand the pool of qualified secondary science teachers through two primary means. First, by improving science teacher *recruitment*, i.e., increasing the number of students and science professionals entering science teacher preparation programs, and second, by reducing science teacher *attrition*, i.e., decreasing the number of science teachers leaving the profession. In this study, I focus on science teacher attrition, as the failure to retain science teachers in the profession may play a greater role than recruitment in the science teacher shortage (Ingersoll & Perda, 2009; Sutcher et al., 2019).

Early career teachers have the highest rates of attrition (Perda, 2013), with some deciding to leave the profession within the first year of teaching (Ingersoll, Merrill, & Stuckey, 2014). Despite this timeline, the current research on teacher attrition assumes that the factors compelling teachers to leave the field arise only once teachers enter the profession. Similarly, the existing literature on teaching commitment assumes that teachers enter the field fully committed to a long-term career in teaching. I propose that by making these assumptions, we are ignoring the possibility that science teachers enter the classroom with varying levels of commitment to teaching due to their experiences as preservice teachers. I have conducted this

qualitative research study employing a multi-case study methodology to learn more about the impact of a science teacher preparation program on its students' commitments to remain secondary science teachers. My work is motivated by the following question: Can a science teacher preparation program influence beginning science teachers' commitment to teaching, and thus their likely retention in the science teaching profession? I followed a cohort of pre-service science teachers from their first science teaching methods course until their graduation to understand how their commitments to the science teaching profession changed and what elements of their science teacher preparation program contributed to those changes.

Literature Review

In this section, I review relevant literature to describe the nature of the science teacher shortage, explain how recruitment and attrition contribute to the science teacher supply, and describe the common elements of science teacher preparation programs.

The Teacher Shortage

Sutcher et al. (2016) define teacher shortage as "the inability to staff vacancies at current wages with individuals qualified to teach in the fields needed." The current teacher shortage became evident as the nation's economy began to recover from the Great Recession of 2008. During the recession, school districts across the nation saved money by implementing hiring freezes and increasing maximum class sizes, allowing them to employ fewer teachers (Partelow & Baumgardner, 2016). As the economy began to recover, hiring resumed and school districts found themselves unable to fill vacancies (Dee & Goldhaber, 2017; Rich, 2015; Sutcher et al., 2016). Pre-pandemic estimates put the teacher shortage at over 100,000 teachers per year (Garcia & Weiss, 2019; Sutcher et al., 2016), but this number is growing as concerns over

COVID-19 have led to a spike in teacher attrition (Carver-Thomas et al., 2021) and a weakened teaching commitment in those remaining in the field (Zamarro et al., 2021).

Garcia and Weiss (2019) argue that the magnitude of the teacher shortage is greatly underestimated if we consider the number of current teachers who are not highly qualified in their subject areas. The most prevalent definition of a highly qualified teacher comes from the No Child Left Behind Act of 2001, which considers teachers highly qualified who hold at least a bachelor's degree, are fully certified by their state's department of education, and have demonstrated competency in the subject area they teach (U.S. Department of Education, 2005). Teacher qualification matters because students taught by highly qualified teachers have higher levels of academic achievement than their peers taught by unqualified teachers (Lee, 2018; Seebruck, 2015). This relationship has been demonstrated across grade levels and subject areas, but is particularly important for secondary science students, who demonstrate not only greater achievement in high school but are also more likely to pursue STEM majors in college when taught by highly qualified teachers (Lee & Mamerow, 2019).

The teacher shortage is not universal, but rather is highly concentrated in certain subjects and schools. It is felt most acutely in special education, mathematics, and science, and in schools located in high poverty and/or high minority communities (Aragon, 2016; Dee & Goldhaber, 2017; Ingersoll, 2011; Sutcher et al., 2016; Viadero, 2018). In the 2017/2018 school year, 43 states reported shortages in science (Addressing Teacher Shortages Act, 2019). Science teachers are among the least likely to be highly qualified (Ingersoll, Merrill, & May, 2014), especially those teaching in high poverty and/or high minority schools (Kahle & Kronebush, 2003; Sutcher et al., 2016). This suggests that the actual magnitude of the science teacher

shortage is greater than reported and that students from our most vulnerable populations are bearing the brunt of the shortage.

The Teacher Supply

The supply of science teachers at any point represents a balance between those entering science teaching (including recent graduates, career changers, and those returning to the field after an absence), those remaining in science teaching, and those leaving science teaching (due to family leave, career changes, or retirement) (Ingersoll & Perda, 2009; Sutcher et al., 2019). To ameliorate the science teacher shortage, we can increase recruitment into science teaching or decrease attrition from science teaching (Ingersoll & May, 2012; Sutcher et al., 2016). Increasing recruitment into science teaching has proven challenging, as fewer high school graduates are interested in teaching (ACT, 2015) and enrollment into teacher preparation programs has declined (Aragon, 2016; Sutcher et al., 2016). Further, the literature provides universities with little guidance as to how to increase recruitment into their teacher preparation programs (Allen, 2005; Luft et al., 2011; See et al., 2020).

While attempts to remedy science teacher shortages have focused primarily on increased recruitment, Ingersoll has argued across numerous studies that the supply of science teachers is sufficient and we should instead focus on decreasing the pre-retirement attrition of science teachers (Ingersoll, 2011; Ingersoll & Perda, 2009; Ingersoll & May, 2012). The importance of science teacher retention has been echoed by many others (Dee & Goldhaber, 2017; Garcia & Weiss, 2019; Sutcher et al., 2016; Viadero, 2018). Science teachers choose to leave the profession before retirement due to a combination of low pay, a negative school environment, and a lack of support (Garcia & Weiss, 2019; Ingersoll & May, 2012; Sutcher et al.,

2016; Viadero, 2018). Science teachers are also more likely to leave the profession if they are not highly qualified (Garcia & Weiss, 2019), enter the profession through alternative pathways (Sutcher et al., 2016), have weak pedagogical preparation (Ingersoll, Merrill, & May, 2014; Sutcher et al., 2016), and teach at high poverty and/or urban schools (Garcia & Weiss, 2019; Ingersoll & Perda, 2009). Retention is also closely tied to another measure, commitment to teaching (Coladarci, 1992; Torres, 2012), so much so that teacher retention and teacher commitment are sometimes used synonymously (For example, see Guarino et al., 2006).

Commitment to teaching is defined by Chestnut and Burley (2015) as "the psychological bond that an individual has with teaching, as a role, as an occupation, and as an institution." Teachers with low levels of commitment to teaching are more likely to leave the profession than their committed counterparts (Coladarci, 1992; Day et al., 2005; Torres, 2012); the impact of commitment on retention may be the greatest for early career, science, and mathematics teachers (Coladarci, 1992). While a review of the literature reveals a paucity of recent research on teaching commitment in the United States, especially that specific to commitment of science teachers, previous studies have identified factors associated with stronger commitments to teaching, including induction support (Day et al., 2005; Weiss, 1999), autonomy (Ingersol & Alsalam, 1997; Weiss, 1999), and self-efficacy (Coladarci, 1992; Chestnut & Burley, 2015). Fortunately, commitment to teaching is not a fixed attribute, but one that can change throughout a teacher's career; Torres (2012) explains that:

> Commitment is not something that teachers have when they enter and lose when they leave. Rather, commitment is constantly developing and evolving throughout a

teacher's career. Commitments change as teachers experience different factors and circumstances in their various contexts.

Suggestions to strengthen commitment to teaching are remarkably similar to those used to improve teacher retention, although the research on retention is both more robust and recent than that on commitment to teaching.

To retain science teachers and reduce the rate of attrition, recommendations include increasing pay (Ingersoll & May, 2012; Ingersoll & Perda, 2009; Sutcher et al., 2016), increased teacher autonomy (Ingersoll & May, 2012), providing professional development opportunities (Ingersoll & May, 2012), ensuring strong pedagogical preparation (Ingersoll, Merrill, & May, 2014), improved job conditions (Ingersoll & Perda, 2009; Sutcher et al., 2016); and strengthening school leadership (Ingersoll & Perda, 2009; Sutcher et al., 2016; Viadero, 2018). Increased retention of science teachers in the profession has benefits beyond simply reducing the science teacher shortage. Recruiting and training a new teacher to fill a vacant position is costly, with estimates exceeding $20,000 (Carver-Thomas & Darling-Hammond, 2017); therefore, retaining science teachers saves money that can be used to buy supplies and fund other educational initiatives. Most importantly, the retention of science teachers may improve the quality of teaching, and in turn, student learning outcomes, by increasing the likelihood that students will be taught by science teachers with more years of teaching experience and greater subject-area expertise (Lee & Mamerow, 2019; Sorensen & Ladd, 2018).

Although teachers may choose to leave the profession at any point in their careers, beginning teachers are particularly vulnerable, having the highest rates of attrition among all teachers. More than 42% of teachers leave within the first five years of teaching (Perda, 2013),

with many deciding to leave teaching within the first year (Ingersoll, Merrill, & Stuckey, 2014). While studies have demonstrated that the components of pre-service teacher education (such as pedagogical preparation) may impact the likelihood of one's retention in science teaching (Ingersoll, Merrill, & May, 2014; Sutcher et al., 2016), they all seemingly assume that science teachers enter the profession fully committed to teaching. Given that many teachers decide to leave teaching within the first year (Ingersoll, Merrill, & Stuckey, 2014), is this assumption sound, or can antecedents of attrition arise before a science teacher ever sets foot in a classroom?

Science Teacher Preparation

In the United States, science teacher certification is regulated at the state-level. These state-level regulations, in turn, provide a framework that informs the development of teacher preparation programs at a state's colleges and universities (Olson et al., 2015). However, even within a given state, the structure of teacher preparation programs varies tremendously from one institution to another, bringing Wilson et al. (2001) to conclude that:

> There is no single phenomenon, no monolith called ''teacher preparation.'' So, while the phrase ''teacher preparation'' seems familiar to us all, it is falsely so, for teacher preparation means many different things across the United States.

More recently, the differences in teacher preparation structure were demonstrated specifically among science teacher preparation programs by Tillotson and Young (2013), who found that programs may require:

> …varying amounts of science content coursework, varying numbers of science methods courses, variable field placements at multiple grade levels in socio-economically and

> culturally diverse schools, specialized courses in technology, assessment, and/or science-technology-society applications, and differing levels of emphasis on the nature of science.

Science teacher preparation programs also vary in the type of pathway they offer, whether traditional, undergraduate certification pathways or alternative, post-graduate certification pathways (Olson et al., 2015; Tillotson & Young, 2013).

Still, some similarities can be observed between science teacher preparation programs. Science teaching methods coursework, science content coursework, and a student teaching placement are all common, if not universal, components of science teacher preparation programs (Olson et al., 2015; Tillotson & Young, 2013). Similarities also exist between programs that pursue accreditation through the Council for Accreditation of Education Programs (CAEP), which utilizes standards set by the National Science Teachers' Association and the Association for Science Teacher Education for science teacher preparation programs (Morrell et al., 2020). These standards are guided by a social justice orientation to science teaching and detail content knowledge, content pedagogy, learning environment, safety, student learning, and professional knowledge and skills benchmarks that should be attained by pre-service science teachers before entering the profession (Morrell et al., 2020; NSTA, 2020).

Research into the efficacy of the common components of science teacher education is scarce (NRC, 2010; Olson et al., 2015; Tillotson & Young, 2013), as is research into the formation of science teacher beliefs and practices, including those related to commitment to teaching, during pre-service teacher education (Tillotson & Young, 2013). In this study, I will explore pre-service science teachers' commitments to the teaching profession, and the impact

of their teacher preparation program on those commitments. The research question guiding this study are:

- How do six pre-service teachers' perceived commitments to the science teaching profession change over the course of a science teacher preparation program?
- What elements of their science teacher preparation program contributed to their commitments to the science teaching profession?

These research questions were developed in service of the broader question that motivates this study: Can a science teacher preparation program influence beginning science teachers' likely retention in the science teaching profession?

Methods

Author Positionality

I grew up in rural Pennsylvania, where I attended public schools. As a first-generation college student, I was inspired to pursue science by my high school biology teacher. Upon graduation from college, I worked in science research for two years before becoming a high-school biology teacher through an alternative certification program. I taught for seven years before leaving the classroom to pursue my PhD in curriculum and instruction at Mid-Atlantic State University (described in more detail below). While a doctoral student, I worked as a teaching assistant for the University's initial science teaching methods course, where I met my participants. Although all data collection took place after the conclusion of the course, it is possible that my affiliation with the University's College of Education impacted the responses of my participants.

Setting and Participants

Mid-Atlantic State University (MASU) is a public research university of approximately 40,000 students located just outside of a major U.S. city. At MASU, education programs are housed in the College of Education (COE). The COE offers students three pathways to become secondary science teachers. In the traditional pathway, students earn dual bachelor's degrees in science and education and a teaching certificate in their science content area in four years. In the alternative pathway, students who have previously earned a bachelor's degree in science earn a master's degree in education and a teaching certificate in their science content area in one year. In the hybrid pathway, students first earn a bachelor's degree in science, then a master's degree in education and a teaching certificate in their science content area in five years. Completion of the edTPA, a national, subject-specific performance-based assessment for pre-service teachers (AACTE, n.d.), is a requirement for all pathways. All pathways also require students to complete a teaching internship. In the traditional pathway, this internship occurs during the last year of the program. These students complete a part-time placement during the fall semester, where they spend one day a week in a mentor's classroom, and a full-time placement during the spring semester, where they gradually take on all teaching responsibilities under the supervision of a mentor teacher. In the alternative and hybrid pathways, students complete a full-time teaching internship, concurrent with their graduate coursework, which spans an entire academic year.

I recruited participants and collected data on the campus of MASU. I first met my participants during the fall semester of their junior years when they enrolled in an introductory science teaching methods course at MASU's College of Education. While this methods course is

a requirement for all preservice science teachers at MASU, it also satisfies a general education requirement and is taken by students with varying levels of interest in teaching secondary science. I was the teaching assistant for the methods course during this semester. Of the twenty-four students enrolled in the course, seven decided to pursue secondary science teaching and applied to the COE the semester following the methods course; all were accepted in the COE's secondary science teaching preparation programs. I recruited six of these preservice science teachers to participate in this study throughout the remainder of their time at MASU; they will be referred to as my cohort hereafter.

All members of my cohort graduated with degrees in education and earned teaching certification in their secondary science content area. Everyone in the cohort taught science in the public-school districts surrounding MASU the year following their graduation from the program. The cohort is diverse in terms of gender, race/ethnicity, and the pathway they chose to enter secondary science teaching. Their self-reported background information is included in Table 1.

Table 1

Self-reported background information

	Gender	Racial/ethnic background	Undergraduate science major	COE pathway to certification
Eric	Male	White & Native American	Biology	Hybrid pathway
Bryan	Male	White	Biology	Traditional pathway
Sarah	Female	Indian	Biology	Traditional pathway
Alice	Female	Chinese-American	Biology	Traditional pathway
James	Male	Asian-American	Chemistry	Traditional pathway
Tom	Male	White	Biology	Traditional pathway

Data Collection

Data sources include a survey and two semi-structured interviews. I surveyed my cohort immediately after their completion of the introductory science teaching methods to learn more about their backgrounds, experiences in science, and interest in science teaching. The 18-item survey was informed by the literature on preservice science teacher recruitment, and included both open-ended questions (for example, “What is(are) your major(s)?”) and dichotomous questions (for example, “Has anyone encouraged you to become a science educator?”). Participants completed the survey online.

I first interviewed my cohort at the beginning of the spring semester of their junior years. At this point, they had all applied to the COE but had not yet received their acceptances. I used a semi-structured interview protocol containing 30 to 40 items; each participant’s

interview protocol was individualized based on their responses to the pre-interview survey (Figure 1). Items included in the survey were based upon the literature on preservice science teacher recruitment and were refined based on input from science education colleagues in the COE.

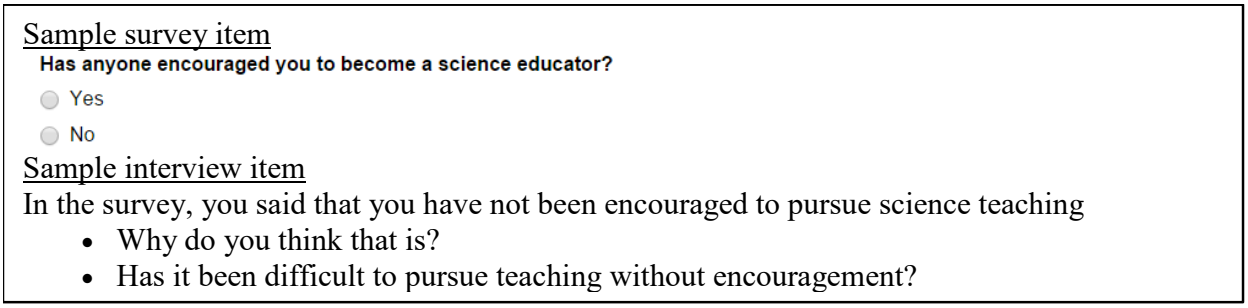


Figure 1. Sample corresponding survey and interview

Each participant was interviewed a second time immediately before their graduation from the COE. Depending upon their chosen pathway to science teaching certification (traditional or hybrid), this interview took place sixteen to twenty-eight months after the initial interview. I used a semi-structured interview protocol containing 33 items. Excepting minor alterations based on pathway, all participants were interviewed using the same protocol. Some interview items were repeated or modified versions of those used in the first interview, while others were unique to the second protocol. All items were subject to the review and scrutiny of my colleagues in science education.

Both interviews were conducted at the COE. Interviews were audio recorded. While no notes or artifacts were collected from the interviews, I composed analytic memos following the conclusion of each interview. I used InqScribe digital media transcription software to transcribe audio-recordings of the interviews.

Data Analysis

This analysis was conducted using a multi-case study methodology (Bogdan & Biklen, 2007), where each member of my cohort represented a unique case. To answer my research questions, I conducted both within-case and cross-case analyses (Ayres et al., 2003). To construct these cases, I began by open coding all transcripts, assigning descriptive codes to participants' responses. This enabled me to gain the familiarity needed to develop a rich understanding of the information they shared with me. I then reviewed these descriptive codes in light of my research questions, highlighting those directly related to teaching commitment, the teaching profession, and the teacher preparation program. I constructed descriptive themes to encompass these highlighted portions. These themes served as deductive codes for a second round of coding, to ensure that I captured all parts of each transcript that related to my research questions. After the second round of coding, I compared both rounds of coding and revised my themes to include all additional information that seemed relevant to a participant's experience in the program and commitment to teaching.

Using these coded transcripts and constructed themes, I characterized each participant's commitment to science teaching at the beginning of their science teacher preparation program (Time A) and at the end of their science teacher preparation program (Time B). I then compared their commitment at Time A and Time B to determine whether their commitment to science teaching had strengthened, weakened, or remained the same. Once I characterized each participant's commitment to teaching, I reviewed their coded transcript to identify related factors; for example, if a participant's commitment to science teaching weakened, I looked for negative comments, disappointing experiences, etc. that could help

explain their change in commitment. After identifying the factors that contributed to changing or stable commitments, I evaluated whether they were potentially influenced by or related to the science teacher preparation program.

After analyzing each case individually, I compared cases to determine the prevalence of change or stability in commitment to teaching, the prominence of the factors implicated in change or stability in commitment to teaching, and how the science teacher preparation program at MASU impacted its students' plans to remain science teachers after gaining science teaching certification.

Findings

In this section, I describe changes that occurred in my participants' commitments to the science teaching profession over the course of their science teacher preparation program at MASU and detail factors that may have contributed to their varying commitments to remain in science teaching. These findings emerged from the cross-case analysis of the six participants' case studies and are supported by representative quotes from our interviews.

Changes in commitment to teaching

Commitment to the science teaching profession varied among my participants over the course of their science teacher preparation program, with some remaining consistently committed to a future as a science teacher while others underwent evolving levels of commitment to teaching. Figure 2 depicts my participants' commitments to science teaching from the beginning of their initial science teaching methods course (the start of their junior year) until their graduation from the program. A solid blue bar/arrow indicates a period of stable commitment to science teaching, while a bar/arrow with a blue gradient indicates a

period of evolving commitment to science teaching and a gray bar/arrow indicates a period when the participant was interested in or committed to an alternate career path. The vertical lines designate the occurrence of other relevant events during the program, as detailed in the legend. Two participants, Sarah and Bryan, experienced significant changes in their commitments to teaching after entering the program, with Bryan developing a strengthening commitment to science teaching while Sarah's commitment diminished over the program. All other participants remained committed to teaching throughout their programs. Each of the three commitment trajectories – strengthening, weakening, and stable – are characterized in greater detail in the following.

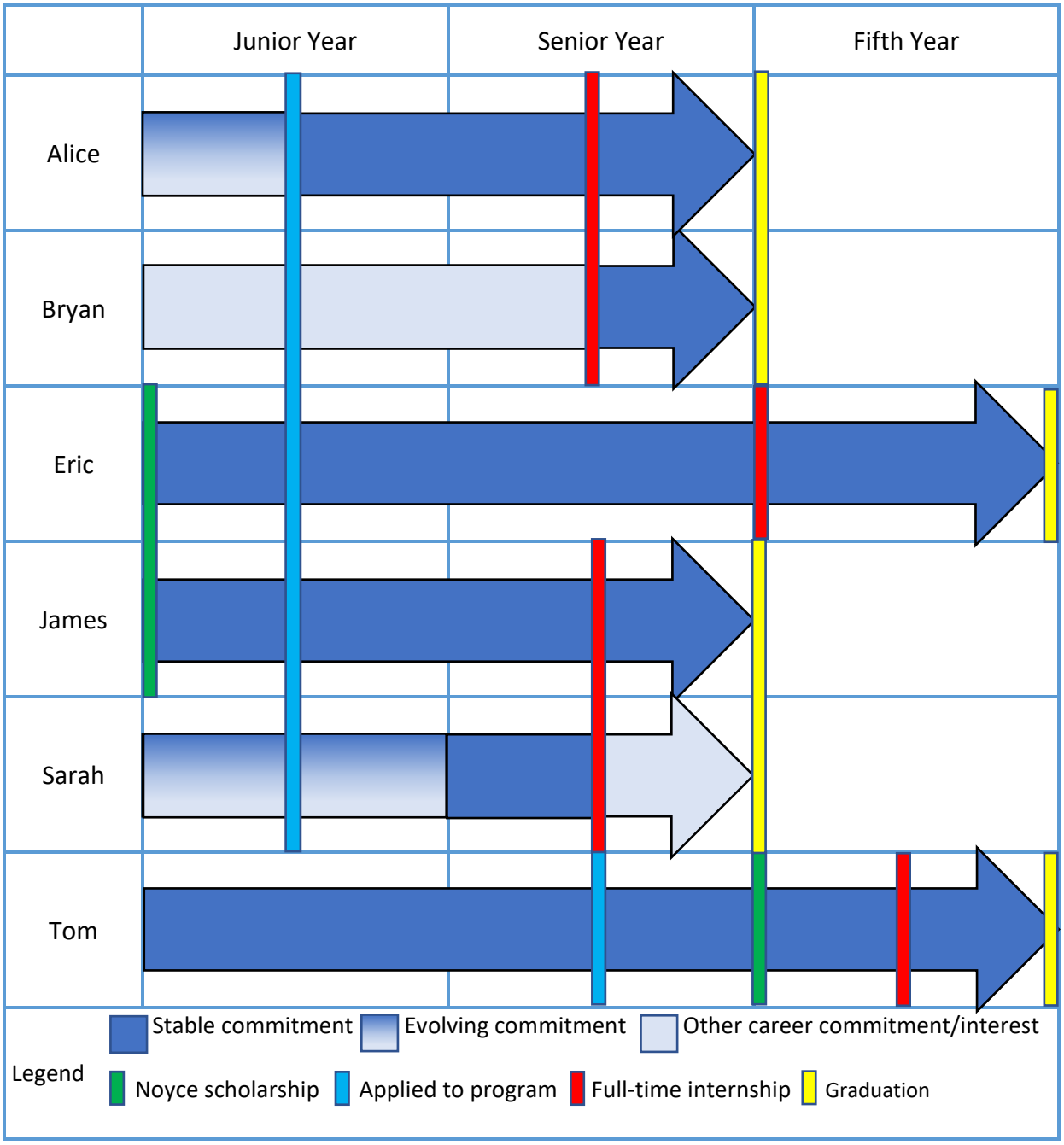


Figure 2. Journey map of participants' teaching commitment throughout program

Strengthening commitment to teaching – Bryan

When Bryan applied to MASU's secondary science teaching preparation program during his junior year, he viewed teaching "as backup plan, just in case." Bryan had no intention of actually entering the teaching profession since he had already received a job offer in politics, a

field he was very passionate about. This level of commitment persisted until the second semester of his senior year, when Bryan began his full-time student teaching internship, which he admits "made me change what I want to do with my life":

> I was never actually planning to be a teacher even though it was my major, a lot of people don't know that… what I was always planning on doing was something political. I've always been really politically active, and I was actually offered a job with the governor, but the internship changed my mind. And now I'm definitely wanting to teach.

During the internship, Bryan proved himself a capable science teacher and formed close, mutually gratifying relationships with his students and mentor. Bryan was moved by the possibility of making a positive impact on his student's lives, the very goal he had hoped to achieve as a politician, saying that "even if you only significantly influence one or two of the hundred-some students you have all day, that's still worth it to me to do that as a career." He also realized how happy teaching makes him feel, marveling:

> I get excited for Mondays! I was thinking one day, wait a second, tomorrow is Monday and I'm happy. I think I should do this for my career.

When we spoke at the end of Bryan's internship and preparation program, he was ready to accept a job offer in teaching and felt that he would remain a science teacher for at least five years, while he expected to work in education or a related field throughout his career.

Weakening commitment to teaching – Sarah

Sarah experienced a dramatic change in her commitment to science teaching over the course of the science teacher preparation program. Like Bryan, Sarah viewed science teaching

as “just a backup plan” when she decided to apply to the program during her junior year. Her reservations were driven by her long-term interest in science, her experience in a summer science research internship program, and her concern that a career in teaching would fail to satisfy her desire to remain engaged in science. However, after Sarah decided to apply to the program, she “started to see it as a more realistic option” and by her senior year she felt “100% sure about teaching.” This change in her career plans was particularly influenced by her experience in the COE’s initial science teaching methods course, which includes an early field experience in a local high school. She explained that observing teachers who were ineffective “made me want to change that and to be that teacher who pushes students to do better.”

Sarah’s decision to commit to a career as a science teacher was ultimately unmade by her experience during the internship, even though Sarah considered it to be the best part of the program. She was surprised to find herself less interested in the science content than in the relationships she was forming with her students, which motivated an interest in counselling:

> Seeing how the teacher is more than just the person who delivers the science content, you deal with students who are having some sort of emotional crisis or students who are having anxiety about college or exams… I didn't really expect to have such meaningful relationships. I definitely expected to enjoy working with kids and have some sort of relationship, but I didn't think it would be this… I'm really interested in counselling and this experience has pushed me to further explore that option.

While Sarah expressed an intension to teach for at least a year, she plans to explore options for pursuing a degree in counselling and does not expect to be teaching science in five years.

Stable commitments to teaching – Alice, Eric, James, and Tom

Alice, Eric, James, and Tom entered the science teacher preparation program planning to become science teachers, and each remained committed to the teaching profession at the end of the program. Both Eric and James decided on science teaching at the beginning of college, with Eric sharing that "from day one, I knew that I was going to be an education major." Alice and Tom's decisions to teach science arose later in college, after trying out several other career pathways. Alice decided to become a science teacher shortly before she applied to the COE's secondary science teaching preparation program, because, as she explained, "one of the best ways to influence someone is through teaching… it appeals to my interests in science but also as someone who likes to work with kids." Tom explained that after switching his major from mathematics to biology, he discovered that:

> I like biology, it's kind of hard, but I also like teaching, and it just kind of worked out so my junior year I decided to put the two together… teaching has always kind of been my first goal, and then biology came secondly.

The teaching commitments of Tom, Eric, and James are more formal, as they are contractually committed to teach for two (Tom) or four (Eric and James) years as a result of their participation in MASU's Noyce Scholars program.

Even though Alice, Eric, James, and Tom expect to still be teaching in five years, their long-term retention in the profession is less certain. Looking beyond the five-year mark, the commitments of Eric, James, and Tom shift from science teaching specifically to education more broadly. Eric plans to remain a science teacher until he has "achieved mastery of

teaching", at which point he would "do something else in the field of education." James is interested in eventually learning more about education administration, although he also views his chemistry degree as a back-up plan, explaining:

> One of the reasons why I got a double degree in chemistry and education is because I wanted to open a little more other than teaching just in case I wanted to do something else. And so I might go into pharmacy if I wanted to.

Tom remains open to all options within education, explaining:

> [There is] a possibility of me doing anything, whether it's staying in a classroom in a high school setting, staying in a middle school, professional development, administration, or moving onto college education, those are 5 different options right there and I think any one of them is equally likely right now.

Before entering the program, none of the participants had considered jobs in education beyond teaching. Eric had even expressed disdain for those who worked in education administration and policy, considering them an impediment to the work of teachers. Among my participants, Alice alone entertained no discussion of eventually leaving the classroom; however, she did share fears about a long-term career in teaching: "My perspective is that the longer you teach, you get more hardened. And I think that's kind of sad and it's a fear for myself. What will I be like in a few years?"

Influence of program on changes in commitment to teaching.

Upon their graduation from MASU, my participants' perceptions of both their science teaching preparation program and the teaching profession were mostly positive, regardless of their level of commitment to teaching. As discussed in my literature review, there is no

universal structure to which science teacher preparation programs adhere; however, they generally provide pre-service science teachers with a student teaching internship and coursework, including one or more science methods courses. Both of these components influenced my participants' commitments to teaching.

Student teaching internship

All participants considered the student teaching internship to be the most important experience they received in the program. Bryan considered it to be the best part of the program because it "made me change what I want to do with my life;" in particular, he was moved by the possibility of making a positive impact on his student's lives, saying that "even if you only significantly influence one or two of the hundred-some students you have all day, that's still worth it to me to do that as a career." Sarah praised her "really great mentor teacher" who "focused more on building my classroom management versus just focusing on the content we were covering"; she also appreciated the opportunity to be "a positive factor in students' lives," further articulating: "You are the teacher, you're delivering instruction but at the same time you are impacting the student moving forward." Ultimately, the internship motivated Bryan and Sarah to change their career plans; although both viewed their experiences positively, Bryan was inspired to commit to teaching science, while Sarah decided that she would rather find a career that allowed her to focus exclusively on helping young people.

Alice, Eric, James, and Tom, who maintained their commitment to science teaching throughout the program, appreciated the opportunity to put ideas learned in their coursework into practice during their student teaching internships. Alice shared that the internship gave

her the opportunity to find "the middle ground between what we learn and what we can actually do in our classes." Tom appreciated "the little wins" each day in the classroom and the chance to enact what he learned in his coursework, sharing that "all the ideas that we talk about right now, I can implement right away and see how they work with me." Although all participants expressed anxiety about beginning their internships, they were satisfied with the progress they made throughout the internship and felt prepared to take on their own classrooms after graduation. Eric explained that while he was very nervous to begin his full-time internship, working with his mentor and students had taught him "a lot in terms of teaching" and that he expected to have "a smooth transition into the world of teaching." Everyone in the cohort except James was initially motivated to teach by their desire to work with young people, still, they were all surprised by how strongly they came to value the relationships they built with their students. Eric appreciated the opportunity to build relationships with his students, drawing from "their energy and positivity" and realizing that:

> If they understand me, then they'll understand that I care about them and that I want them to succeed - that if I ask them to do something, it's for their success. And they're more likely to do it.

Tom also enjoyed his students, sharing that "at the end of the day I'm walking away from them happy to have taught them… that keeps you going." Ultimately, building relationships with students during the internship even became a motivating factor for James, who explained:

> I enjoyed being there just because my students were there… it's the relationship that I've built with them that has allowed me to really enjoy every day of being there. There wasn't a single day when I was like, 'I don't like this' or 'I don't want to be here.'

For Alice, Eric, James, and Tom, the internship provided an opportunity to try out and affirm their identities as science teachers, which fortified their commitments and reinforced their decisions to become science teachers.

Despite their positivity around the student teaching internship, participants did share some concerns about the experience. Bryan, Eric, and James felt there was a lack of transparency around internship placements in the program - they expected an opportunity to share their preferences for placement, but that never materialized. Eric complained that he "had to ask questions over email, and it was ambiguous, and no one would get back to me… I was placed without anyone contacting me." Ultimately, Bryan and Eric were able to restructure their internships to provide the experience both desired, but only after repeated attempts at contact. Although Bryan loved his internship experience, he would like to see changes in the internship structure so that interns spend more time in their initial placements and more time in the classroom overall, sharing that interns need "as much time in the schools as possible" and less time in classes because "there's no better way to prepare to teach than having you do it more and earlier." Given the importance of the internship in my participants' commitments to teaching, and the wide variation in internship experiences the participants encountered, the program should work with students to select the best fit from available placements, rather than assign placements in a seemingly arbitrary way.

Coursework

In addition to their general education requirements, my participants completed coursework in their science content areas and in education, ultimately earning either dual bachelor's degrees (Alice, Bryan, James, Sarah, and Tom) or a bachelor's and master's degree

(Eric). To understand the impact the science teacher preparation program had on my participants' commitments to teach science, I focused on their experiences in education courses. Overall, they shared praise for the quality of instruction and content, with Alice explaining that "teachers who teach about teaching are good at it… that's definitely been a nice change from my normal science courses," and Sarah praising the faculty for being "really great at preparing you and just being an open resource."

The COE's science teaching methods coursework was spoken of positively by all participants. While participants struggled to find applicability in the general education coursework that included students from all secondary content areas, they considered their science methods coursework to be richly influential on their teaching practice. James shared that before beginning his science methods coursework, he thought that science "was just knowing vocab, just knowing these conceptual things," but that changed due to his science methods courses' focus on "nature of science and how to incorporate it into our lessons." All participants praised their science methods instructors and described the ways in which they impacted their view of the profession; Bryan explained that his instructors "really showed you how important it is to teach through inquiry and how important it is to keep kids engaged." The science methods courses also provided an opportunity for preservice science teachers to connect with one another and form relationships – all participants referred to at least one other participant during their interviews. Speaking of the cohort, Sarah shared that "we are definitely really supportive of one another, and that's been really helpful… we're able to collaborate", a feeling echoed by Tom, who explained "if any of us need help, I know we would help each other out."

Despite my participants' positivity about their experiences in the COE, they also noted concerning gaps in their education coursework. As part of their course requirements, all participants completed a diversity course with a dual focus on English-language learners and special education. Alice, Bryan, James, and Sarah were critical of the course. They complained about the placement of the course, which they took during their last semester while in their full-time student teaching internship, arguing that the course should be offered prior to the internship so that students enter student-teaching armed with the skills necessary to differentiate their instruction. James was particularly frustrated by the lack of preparation around differentiation, explaining that:

> I was just so overwhelmed by preparing the lesson that I had that I didn't really have time to make an entire modification for just one student… if I knew how to do that effectively, then I could've incorporated it here and there in the lessons, but I just didn't know what to do.

Alice and Sarah also considered the course to be poorly structured with unprepared instructors; Alice shared that the class was "very informal" and "hard to take it seriously". However, Tom spoke positively about the course and considered its placement beneficial, as it enabled him to immediately apply what he was learning.

Tom was the only participant who felt that the program had sufficiently prepared him to meet the classroom management challenges of his internship. Alice repeatedly discussed her struggles with classroom management, considering it to be her greatest weakness as a teacher; she could not recall receiving any instruction around classroom management in the program but wished that it had included "more practice learning how to do classroom management,

more strategies… when it comes to disciplinary issues, that would have been helpful." Similarly, Eric struggled with classroom management and shared recommendations for improving the program's instruction around the topic but expressed with frustration that since "there's nothing on classroom management as of now, anything is better than nothing." Sarah also felt unprepared for classroom management challenges, explaining that:

> We didn't focus as much about what obstacles you might face starting out… I expected to have this ideal classroom where all the kids want to learn and they're all excited and participating, and then when you're actually there you're like, oh, okay, nobody except these two kids want to answer any questions and how do I get kids to do stuff?

Although all participants felt they had developed some measure of classroom management competence during their student teaching internship, many still felt unprepared and concerned that the effectiveness of the skills and strategies they learned may not carry over to their first-year teaching placements.

Tom was also the only member of the cohort who felt prepared for daily lesson planning upon beginning his student teaching internship. Bryan found daily lesson planning overwhelming, explaining that the program had required him to create "maybe one or two lesson plans… but we should be doing that every day in the program." Eric and Sarah recalled little or no instruction around lesson planning, with Sarah expressing: "I don't think it was ever explicitly stated, this is how you make a lesson plan… I had to learn on my own." As with classroom management, the participants felt more comfortable with lesson planning by the end of their internships, but worried about their ability to meet the demands of daily lesson planning once they entered the profession. While participants' perceived lack of preparation

around classroom management and lesson planning did not impact their initial commitments to teaching, they did express fear that the ongoing challenges of classroom management and lesson planning would lead to burnout, a feeling that has been associated with weakening commitment to teaching (Brown & Roloff, 2011; Jones & Youngs, 2012). These gaps in my participants' science teaching preparation are also concerning because issues related to classroom management and lesson planning are widely reported contributors to teacher attrition (Garcia & Weiss, 2019; Ingersoll & May, 2012; Ingersoll, Merrill, & May, 2014; Sutcher et al., 2016).

Discussion

This study explored how the teaching commitments of six pre-service science teachers changed over the course of their science teacher preparation program and sought to identify the elements of the program that contributed to their changing commitments to a career in science teaching. Three major findings are discussed in this section. The first finding is that my participants entered their science teacher preparation program with varying levels of commitment to science teaching, with some never intending to enter the profession. Both Bryan and Sarah viewed teaching as a "backup plan," and only committed to teaching science after entering the program. This finding demonstrates that science teacher preparation programs cannot assume their recruits enter committed to the science teaching profession and should attend to nurturing the teaching commitments of pre-service teachers. Further, this suggests that recruitment is an ongoing process that does not end upon a pre-service teacher's entry into a science teacher preparation program and future research into recruitment must

provide teacher education programs with strategies not only to recruit program entrants but to convert those entrants into committed science teachers.

A second finding is that my participants' commitments to remain science teachers changed, both positively and negatively, throughout the course of their preparation programs, with some crafting exit strategies before graduation. Pre-service science teachers' commitments to teaching are not static. Bryan entered the program planning for a future in politics, but his program experiences inspired him to instead commit to science teaching. Sarah also entered the program uncommitted to becoming a science teacher, but quickly decided that she wanted to teach science – until her program experiences led her to rethink her commitment to teaching science and consider a career in counseling. Accepting Torres' view of commitment as a factor that varies along a continuum, rather than a dichotomous variable, I would suggest that Eric, James, and Tom also experienced a weakening of their commitments to teaching. Although they all expected to be teaching science in five years, by the end of their programs all were entertaining long-term career options outside of the classroom. Along with their weakening commitments to teaching, at the end of the program Sarah, Eric, James, and Tom also shared new concerns about pay, classroom management, differentiating instruction, and burn-out. The existing literature on commitment to teaching and teacher retention assumes that new teachers enter the profession fully committed to long-term careers in teaching and that attrition occurs when teaching conditions lead to a loss of commitment. I have found this assumption to be flawed. Given the overlap between my participants' concerns and the reasons frequently given for teacher attrition, future research on teacher retention

must include a consideration of the influences of teacher preparation programs on teaching commitment.

A third finding is that my participants' experiences in their science teacher preparation program, particularly student teaching internships, contributed to their changing commitments to remain science teachers. My participants all considered the student teaching internship to be the most important component of their science teacher preparation program. The internship led Bryan to commit to a career in science teaching while it led Sarah to consider a different career path. The internship affirmed the career choices of Alice, Eric, James, and Tom, who were eager to assume control of their own classrooms after graduation from the program. While my participants spoke positively of their coursework in general, all except Tom perceived weaknesses in their pedagogical preparation around classroom management, lesson planning, and teaching diverse learners. Although all participants felt they had developed classroom management competency and lesson planning skills during their student teaching internships, many still felt unprepared and concerned that the effectiveness of the skills and strategies they learned may not carry over to their first-year teaching placements. These concerns about perceived gaps in their coursework were not enough to impact participants' initial commitments to science teaching, but they did raise anxiety about the potential for future professional burnout that might impact their long-term teaching commitments. Again, future research is needed that considers the role of preservice teacher preparation in commitment to teaching and teacher retention.

Can a science teacher preparation program influence beginning science teachers' commitment to teaching, and thus their likely retention in the science teaching profession?

While more research is needed, my study of six pre-service science teachers' experience in a science teacher preparation program suggests that student teaching internships influence commitment to teaching, which is a predictor of teacher retention. Further, concerns about classroom management, lesson planning, and differentiating instruction for diverse learners, all factors commonly related to teacher attrition, may arise before teachers begin their first year in the classroom. Science teacher preparation programs may be able to fortify their graduates' long-term commitments to teaching by providing rigorous instruction around these topics.

My conclusions should be viewed in the light of several limitations. My participants were all students in the same science teacher preparation program, so these findings may not be applicable to other programs. My participants were all co-majoring in biology or chemistry; my findings may not apply to pre-service teachers with other science content backgrounds. My participants were also more racially and ethnically diverse and more predominately male than the general teaching population. In addition to being a doctoral candidate in MASU's science education department, I was also teaching assistant for the initial science methods course taken by all participants and teacher for Tom's second science methods course; it is possible that my role in the department and program impacted what was shared by my participants. Finally, it is possible that my participants' perceptions of teaching and teacher self-efficacy also impacted their evolving commitments to science teaching; future research should explore the role of these constructs in commitment to science teaching and science teacher retention.

Conclusions

To learn science, students need access to high quality science teachers. Unfortunately, there is a shortage of these teachers, due to both low recruitment into and high attrition from

science teaching. Tragically, the burden of this shortage – an insufficient or uninspiring science learning experience that precludes the pursuit of the credentials necessary to land the STEM jobs of the future – falls disproportionately upon the shoulders of students from low-income and minority households. Providing all students with access to qualified science teachers is an issue not just of staffing, but of equity, so that increasing the number of science teachers entering and remaining in the profession becomes an issue of social justice.

The existing literature on science teacher retention assumes that all science teachers enter the profession committed to a career in science education, so that attrition from the profession is due entirely to issues that arise after science teachers enter the classroom. In this study of six preservice science teachers, I demonstrate that (a) preservice science teachers enter their preparation programs with varying levels of commitment to remaining science teachers, with some never intending to enter the profession; (b) preservice science teachers' commitment to remaining science teachers changes, both positively and negatively, throughout the course of their preparation programs, with some crafting exit strategies before graduation; and (c) experiences that occur within science teacher preparation programs, particularly student teaching internships, contribute to students' changing commitments to remain science teachers. These findings suggest that science teacher preparation programs may be able to influence beginning science teachers' retention in the science teaching profession, and that we cannot assume the antecedents of attrition arise only once teachers enter the profession. In doing so, we are missing an opportunity to identify and ameliorate the earliest contributors to science teacher attrition.

Chapter 5: Synthesis

My dissertation is focused on understanding the processes involved in mitigating the ongoing shortage of highly qualified science teachers by investigating the factors involved in the recruitment and retention of new science teachers in the profession. In this chapter, I summarize the findings of my two studies and draw upon both to discuss their combined contribution to our understanding of the relationship between recruitment and retention, interest in science teaching and commitment to science teaching. I also discuss the implications of my synthesis across the studies and suggest areas for future research.

Overview of Two Studies

In Chapter Three, I used a content analysis approach to identify the factors that motivated six science undergraduates to apply to a secondary science teacher preparation program and compare their motivations to those described in the literature. I found that although all of the factors identified by the literature as positively contributing to science teaching interest were motivations for some or all of my participants, the existing literature on science teacher recruitment was insufficient and had not captured all my participants' motivations for pursuing science teaching certification. In addition to the factors previously described in the literature, my participants were also inspired by the influence of negative examples, a desire to enter the workforce quickly, identity, and the sense of community found in their University's College of Education.

In Chapter Four, I conducted a multi-case study to determine how the science teaching commitments of six pre-service science teachers changed over the course of their science teacher preparation program and to identify the elements of their science teacher preparation

program that contributed to changing commitments to science teaching. I found that my participants entered the science teacher preparation program with varying levels of commitment to science teaching and that the science teaching commitments of some participants changed over the course of the program. I also found that my participants' commitments to science teaching were influenced by their science teacher preparation program, especially by their experiences in the student teaching internship. Based on these findings and the established connection between commitment to teaching and teacher retention, I concluded that science teacher preparation programs may influence beginning science teachers' likely retention in the science teaching profession.

Discussion Across Studies

Antecedents of Attrition.

Pre-retirement teacher attrition is widely credited as a leading cause of the nationwide shortage of highly qualified science teachers. The literature tells us that many teachers leave the profession within their first five years of teaching (with some making the decision to change careers within their first year of teaching) and offers many reasons for and potential solutions to the problem, all centered around the work conditions and classroom experiences of in-service teachers. Underlying this literature is the presumption that new teachers begin their careers equally and fully committed to teaching, so that those who leave the profession do so entirely based upon their experiences as teachers. This belief, in turn, places the responsibility to retain teachers solely on school systems.

In my second study, I challenge these presumptions. I found that a teacher may enter the field while simultaneously pursuing an alternate career path, and that factors commonly

credited with playing a role in teacher attrition, such as classroom management and teaching diverse learners, have already begun to influence teachers' views of the profession before they enter their first teaching assignments. These findings led me to conclude that science teacher preparation programs may be able to positively and negatively influence their students' commitments to teaching science, and therefore their likely retention in the teaching profession.

Looking across both of the studies included in this dissertation, I find further evidence that antecedents of attrition may arise during science teachers' preparation programs. When interviewing my participants prior to their acceptance into the program, I asked them to identify negative aspects of a future career in science teaching. None of them were concerned about their future salaries. By the end of the program, Bryan, James, and Sarah had developed concerns about their salary potential, with James already planning to work a second job to supplement his teaching income; this is especially concerning because low pay is one of the most commonly cited reasons for teacher attrition.

After salary, the most often cited reasons why teachers leave the profession relate to working conditions, and I found that my participants also developed concerns related to their future working conditions over the course of their preparation program. Prior to entering the program, the decisions of Alice, Bryan, and Tom to pursue teaching were motivated in part by their perception of the work-life balance and schedule enjoyed by teachers. After their internship experience, however, they had come to view this as a negative aspect of a teaching career, sharing concern over the long hours they put in as interns and expecting an even greater imbalance during their first years of teaching. My participants' views of classroom

management, another contributor to working conditions, also changed over the course of their programs. Before entering the program, only Alice and James expressed concern over classroom management, and their concern was limited to urban classroom contexts. By the end of their student teaching internship, all participants considered the difficulty of managing a classroom to be a negative aspect of a teaching career, and only Tom felt that the program had adequately prepared him to meet the challenges of managing a classroom.

Finally, negative school environment and lack of support are also cited as common contributors to teacher attrition. One of the main findings of my first study was the role sense of community played in attracting my participants to the College of Education and, in turn, the teaching profession. They all entered the University as science or mathematics majors but felt out of place among their peers and unsupported by their professors. This sent them searching for belonging, or a sense of community, which they found in the College of Education prior to applying to the program. This feeling continued throughout their teacher preparation program, where they experienced competent, caring faculty and the support of their fellow preservice science teachers. Unfortunately, my participants may not find the same support and sense of community once they enter the classroom as new science teachers and may find themselves once again searching for a career where they feel part of a community.

Identity.

Assumptions about commitment to teaching are limited not only to the literature on teacher retention; the literature on teacher recruitment similarly assumes that pre-service teachers enter teacher preparation programs fully committed to the profession. While this may be true for some recruits (such as Eric and James), I have found that others enter science

teacher preparation programs because they are merely interested in teaching, viewing it as a back-up plan or one among many future career options, and that even when a pre-service teacher's interest in teaching develops into commitment to teaching, this change may not be permanent. I believe that interest in science teaching develops into commitment to science teaching as one develops a science teacher identity, but commitment remains variable as identity is constantly evaluated against new experience in the program.

Identity emerged as a finding in my first study. My participants found the College of Education through a process of self-discovery that began with defining their identity and continued with testing that identity against possible career choices. My participants recognized science teaching as a potential compliment to their identities at different points in their educations; Eric and James entered the University expecting to pursue science teaching, a time when the others were still testing their identities against pathways that would lead them to careers in medicine or research. By their junior year, all participants were exploring the University's science teacher preparation program and were interested in a future career as a science teacher, which led them to apply to the program. At the time of my first interview with my participants, all could be considered successfully recruited.

However, the interest in science teaching that led my participants to be recruited into the program did not automatically equate to commitment to science teaching. Even after their acceptance into the program, Bryan and Sarah continued to view science teaching as a backup plan and identified more closely with careers in politics and research, respectively. Bryan only committed to science teaching after his internship experience, where his aptitude for teaching and the realization that he could make a positive impact upon the world through teaching

challenged his plans for a career in politics and led him to identify more strongly with a career in teaching. Sarah's coursework experiences inspired her to commit to science teaching early in the program, but her plans changed again after the internship, where she identified more strongly with her role as a mentor than with teaching science content. Even participants who entered the program committed to science teaching saw their identities as science teachers challenged; by the end of the program, Eric, James, and Tom were open to the possibility of eventually pursuing careers in education administration and policy. It appears that my participants were continually testing their identities against new experiences in the program.

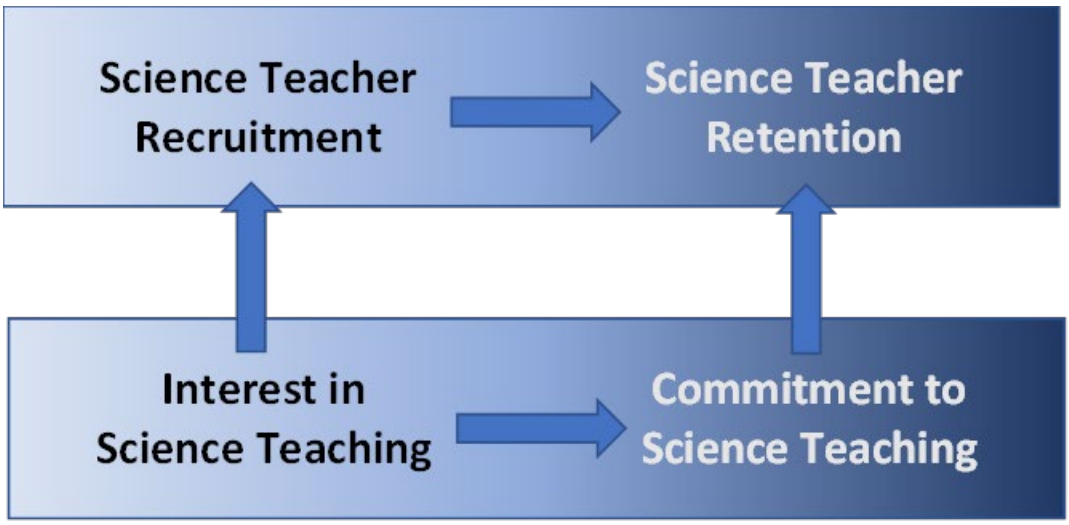
Recruitment to Retention, Interest to Commitment.

To meet the demand for highly qualified science teachers in the United States, the literature tells us that we can focus on increasing the recruitment of undergraduate science majors and science professionals into traditional and alternative science teacher preparation programs, or we can focus on improving the retention of existing highly qualified science teachers in the profession. Researchers have traditionally focused on one end of this recruitment-retention dichotomy, with the bulk of work into ameliorating the science teacher shortage focusing on retention. The three formative graduate assistantship experiences that I described in Chapter Zero led me to focus on recruitment, specifically the recruitment of undergraduate science majors into a science teacher preparation program. However, as I began to study science teacher recruitment, I found it increasingly difficult to ignore retention, which led me to suspect that the polarization of recruitment and retention represented a false dichotomy. A primary goal of this dissertation was to explore and characterize the connection between the recruitment and retention of science teachers by synthesizing the two studies

included as Chapters Three and Four. I propose that there is a link between science teacher recruitment and retention, and it lies in the conversion of interest in science teaching into commitment to science teaching; these relationships are discussed further below and summarized in the following model (Figure 1):

Figure 1

Relationships between recruitment and retention, interest and commitment



An essential precondition for the recruitment of undergraduate science majors into the science teaching profession is interest in science teaching. My participants became interested in science teaching at different points in their educations, from high school (Eric and James) to their sophomore years at the University (Alice and Sarah), and for different reasons, including a desire to work with children (Alice), positive teaching experiences (Sarah), and a desire to make a positive impact upon the world (Bryan). Their interest in science teaching led them to explore course offerings in the College of Education and to enroll in the initial science teaching methods course, where we first met. During the course, they accrued experiences that both bolstered their interest in science teaching and affirmed and aligned with their identities; as a result, they

chose to apply to the COE's science teacher preparation program at the end of their course. At this point, my participants can be said to have been successfully recruited, but I have found that the literature on science teacher recruitment has failed to capture two essential and related components of the nature of their recruitment. First, recruitment into a science teacher preparation program cannot be assumed to automatically translate into recruitment into the science teaching profession. Neither Bryan nor Sarah planned to become science teachers when they applied to and entered the program. Second, programs cannot assume that their recruits enter committed to science teaching, only that they are interested in science teaching.

After a pre-service science teacher is recruited into a teacher preparation program, it falls upon the program to convert their interest in science teaching into commitment to science teaching, and then maintain that commitment; in other words, recruitment is an ongoing process. Science teacher preparation programs have the power to impact commitment to teaching both positively and negatively. For my participants, both their coursework and student teaching internships, essentially universal components of science teacher preparation programs, influenced their commitment to science teaching. Sarah entered her program interested in science teaching but was uncommitted and still planning for a career in science research. Experiences in her coursework led her to change her plans and commit to a future as a science teacher, but this commitment was challenged by experiences in her internship that caused her to reassess her decision and identify more strongly with a future career as a counselor. Bryan also began his program interested in but uncommitted to science teaching, despite positive coursework experiences. He only committed to a future as a science teacher in his last semester in the program, in response to revelatory experiences in his internship.

Interest in science teaching is a requirement for recruitment into science teaching, but it must be converted into commitment to science teaching if science teaching candidates are to be retained in the profession. At the end of the program, Sarah was still interested enough in science teaching to accept a teaching position for the following year. But since she lacked commitment to science teaching, she planned to use this year to explore options for pursuing a degree in counselling, a career path she was inspired to investigate based on her internship experience. Ultimately, Sarah was considering leaving science teaching before she ever entered the classroom because commitment is essential for teacher retention. However, the current literature on science teacher retention is blind to this possibility. If Sarah leaves the profession to pursue another career path after her first year of teaching, it will be assumed that this decision was inspired by the conditions of her teaching placement, when in fact the decision was motivated by events that occurred in her science teacher preparation program. If we assume that Sarah's experience is not unique, then we must look to science teacher preparation programs not only as instruments of science teacher recruitment, but also as a first line of defense against science teacher attrition.

Implications and Conclusions

To recruit greater numbers of undergraduate science majors into science teaching, schools of education and their science teacher preparation programs need a broader and more aggressive presence on college campuses that allows them opportunities to both inspire interest in science teaching and connect with science undergrads with existing interest in teaching. None of my participants felt that they were recruited by their University's College of Education; they all sought out and initiated contact with the science teacher preparation

program after realizing that teaching might be of interest to them, even though establishing contact with the COE often required perseverance. It is likely that more of their classmates were interested in exploring science teaching but lacked the initiative to establish a connection with the COE. We can further imagine that an even greater number of undergraduate science majors never consider teaching science but feel similarly out of place among their science major peers due to interests, strengths, and values that would align more closely with those of other science teacher candidates. We need opportunities and strategies to introduce these undergrads to the possibility of teaching science.

Once science majors have been recruited into science teacher preparation programs, we should focus on actively converting their interest in science teaching into commitment to science teaching by viewing science teacher recruitment as an ongoing process related to the development and maintenance of science teacher identity. We cannot assume that undergraduate science majors who apply to science teacher preparation programs see themselves as future science teachers; teaching may be something that they continue to view as a "backup plan" unless they are provided with experiences that demonstrate the alignment between a career as a science teacher and the interests, strengths, and values that shape their identities. To do this, science teacher preparation programs need to understand why their applicants are interested in science teaching – To engage in science content? To make a positive impact upon society? To work with young people? – and tailor their program experiences to emphasize the components of a career in science teaching that align with their identities. For many candidates, this may mean more frequent and earlier opportunities to work in secondary science classrooms. Such experiences may also serve to strengthen existing

commitment to teaching, as mastery experiences are the primary source of self-efficacy, a factor associated with strong commitment to teaching. By developing and strengthening their students' science teacher identities, science teacher preparation programs can facilitate the conversion of interest in science teaching to commitment to science teaching.

There is also a need to reexamine the structure and focus of science teacher preparation programs to make them better equipped to act as our front-line defense against teacher attrition. They can do this through fortifying and maintaining an existing commitment to science teaching by directly confronting factors that are likely to diminish commitment, since commitment to teaching is related to teacher retention. If apprehensions over monetary compensation are the primary reason science teachers leave the field, then we should acknowledge that early and often in science teacher preparation programs while seeking to alleviate these concerns through providing tuition remission benefits, by equipping prospective teachers with financial planning skills, and by sharing knowledge about the wide variations in salary and benefits among different school systems and states. We can also combat concerns over work conditions by fortifying candidates with classroom management skills and giving them many opportunities to design lessons plans that are differentiated to reach diverse learners. Science teacher preparation programs can also form partnerships with local school systems to augment their science teacher retention efforts by providing induction support and professional development opportunities, both of which are related to increased commitment and retention.

Future research into science teacher recruitment should focus not only on the most effective ways to recruit candidates into science teacher preparation programs, but also on

who we should be recruiting. Teaching commitment is an under-studied area, particularly the commitment of secondary science teachers in the United States. More research is needed to reveal the origins of commitment and ways of strengthening commitment to teaching in both pre-service and in-service teachers. My model of the relationships between recruitment and retention, interest and commitment fails to consider the impact of perception of teaching and teacher self-efficacy; future research should explore the role of these constructs in science teacher recruitment and retention. While retention is a widely studied area, future research must be open to the possibility that the precursors of teacher attrition are present before science teachers ever enter their first teaching placements. Finally, it should be noted that in the time since my data was collected, MASU's science teacher preparation program has undergone a redesign; my analysis and conclusions are not reflective of the current program.

References

ACT. (2015). The condition of future educators, 2015.

Act, E.S.S.A. (2016). Public Law 114-95. In *Washington, DC: US Congress*.

Act, N.C.L.B. (2002). Public Law 107-110. In *Washington, DC: US Congress. Available at: www2. ed. gov/policy/elsec/leg/esea02/107-110. pdf*.

Addressing Teacher Shortages Act of 2019, S. 2367, 116th Cong., 1st Session (2019)

Allen, M. B. (2005). Eight questions on teacher recruitment and retention: What does the research say? Denver, CO: Education Commission of the States.

American Association of Colleges for Teacher Education. (n.d.). About edTPA: Overview. Retrieved from http://edtpa.aacte.org/about-edtpa

Aragon, S. (2016). Teacher Shortages: What We Know. Teacher Shortage Series. *Education Commission of the States*.

Ayres, L., Kavanaugh, K., & Knafl, K. A. (2003). Within-case and across-case approaches to qualitative data analysis. *Qualitative health research*, *13*(6), 871-883.

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological review*, *84*(2), 191.

Bogdan, R.C. and Biklen, S.K. (2007) Qualitative Research for Education: An Introduction to Theory and Methods. 5th Edition, Allyn & Bacon, Boston.

Borgerding, L. A. (2015). Recruitment of early STEM majors into possible secondary science teaching careers: The role of science education summer internships. *International Journal of Environmental and Science Education, 10*(2), 247–270.

Brown, L. A., & Roloff, M. E. (2011). Extra-role time, burnout, and commitment: The power of promises kept. *Business Communication Quarterly*, *74*(4), 450-474.

Bull, K. S., Marks, S., & Salyer, B. K. (1994). Future teacher scholarship programs for science education: Rationale for teaching in perceived high-need areas. *Journal of Science Education and Technology*, *3*(1), 71-76.

Campbell, J. L., Quincy, C., Osserman, J., & Pedersen, O. K. (2013). Coding in-depth semistructured interviews: Problems of unitization and intercoder reliability and agreement. *Sociological Methods & Research*, *42*(3), 294-320.

Carver-Thomas, D., & Darling-Hammond, L. (2017). Teacher turnover: Why it matters and what we can do about it. *Palo Alto, CA: Learning Policy Institute*.

Carver-Thomas, D., Leung, M., & Burns, D. (2021). California Teachers and COVID-19: How the Pandemic is Impacting the Teacher Workforce. *Learning Policy Institute*.

Chesnut, S. R., & Burley, H. (2015). Self-efficacy as a predictor of commitment to the teaching profession: A meta-analysis. *Educational research review*, *15*, 1-16.

Coladarci, T. (1992). Teachers' sense of efficacy and commitment to teaching. *The Journal of experimental education*, *60*(4), 323-337.

Council for the Accreditation of Educator Preparation (2013). *CAEP 2013 standards for accreditation of educator preparation*. Washington, DC. Retrieved from: http://caepnet.org/standards/standards/

Creswell, J. W. (2002). Educational research: Planning, conducting, and evaluating quantitative and qualitative research. Upper Saddle River, NJ: Merrill Prentice Hall.

Cross, F. (2017). Teacher shortage areas. Nationwide listing. 1990–1991 through 2017–2018. Washington, D.C.: U.S. Department of Education, Office of Postsecondary Education.

Darling-Hammond, L., & Berry, B. (1999). Recruiting teachers for the 21st century: The foundation for educational equity. *Journal of Negro Education*, 254-279.

Dawson, V. (2007). Factors influencing pre-service teachers' decisions to become secondary science and mathematics teachers. *Teaching Science: The Journal of the Australian Science Teachers Association, 53*(4), 28–31.

Day, C., Elliot, B., & Kington, A. (2005). Reform, standards and teacher identity: Challenges of sustaining commitment. *Teaching and teacher Education*, *21*(5), 563-577.

Dee, T. S., & Goldhaber, D. (2017). Understanding and addressing teacher shortages in the United States. *The Hamilton Project*.

Dominguez, C. R. C., Viviani, L. M., Cazetta, V., Guridi, V. M., Faht, E. C., Pioker, F. C., & Cubero, J. (2015). Professional choices and teacher identities in the science teacher education program at EACH/USP. *Cultural Studies of Science Education*, *10*(4):1189-1218.

Eick, C. J. (2002). Studying career science teachers' personal histories: A methodology for understanding intrinsic reasons for career choice and retention. *Research in Science Education*, *32*(3), 353-372.

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, *62*(1), 107-115.

Espinet, M., Simmons, P. E., & Atwater, M. A. (1992). Career decisions of K-12 science teachers: Factors influencing their decisions and perceptions toward science teaching. *School Science and Mathematics*, *92*(2), 84-91.

Evans, R. H. (1987). Factors which deter potential science/math teachers from teaching; changes necessary to ameliorate their concerns. *Journal of Research in Science Teaching*, *24*(1), 77-85.

Garcia, E., & Weiss, E. (2019). The teacher shortage is real, large and growing, and worse than we thought. Economic Policy Institute.

Goldhaber, D., Krieg, J., Theobald, R., & Brown, N. (2014). The STEM and Special Education Teacher Pipelines: Why Don't We See Better Alignment between Supply and Demand? CEDR Working Paper. WP# 2014-3. Center for Education Data & Research.

Guarino, C. M., Santibanez, L., & Daley, G. A. (2006). Teacher recruitment and retention: A review of the recent empirical literature. Review of educational research, 76(2), 173-208.

Hodson, R. (1999). *Analyzing documentary accounts* (No. 128). Sage.

Hoff, D., & Lee, C. (1986). Exploring science teaching as a career. *Journal of College Science Teaching*, *15*, 457.

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, *15*(9), 1277-1288.

Hubbard, K., Embry-Jenlink, K., & Beverly, L. (2015). A university approach to improving STEM teacher recruitment and retention. *Kappa Delta Pi Record*, *51*(2), 69-74.

Ingersoll, R., & Alsalam, N. (1997). Teacher professionalization and teacher commitment: A multilevel analysis (NCES 97-069). Washington, DC: National Center for Education Statistics.

Ingersoll, R. M. (2011). Do we produce enough mathematics and science teachers?. *Phi Delta Kappan*, *92*(6), 37-41.

Ingersoll, R. M., & May, H. (2012). The magnitude, destinations, and determinants of mathematics and science teacher turnover. *Educational Evaluation and Policy Analysis*, *34*(4), 435-464.

Ingersoll, R. M., Merrill, L., & May, H. (2014). What are the effects of teacher education and preparation on beginning teacher attrition? Research Report (#RR-82). Philadelphia: Consortium for Policy Research in Education, University of Pennsylvania.

Ingersoll, R. M., Merrill, L., & Stuckey, D. (2014). Seven trends: The transformation of the teaching force.

Ingersoll, R. M., & Perda, D. (2009). The mathematics and science teacher shortage: Fact and myth.

Jones, N., & Youngs, P. (2012). Attitudes and affect: Daily emotions and their association with the commitment and burnout of beginning teachers. *Teachers College Record*, *114*(2), 1-36.

Kahle, J. B., & Kronebusch, M. (2003). Science teacher education: From a fractured system to a seamless continuum. *Review of Policy Research*, *20*(4), 585–602.

Kilinç A., & Seymen, H. (2014). Preservice teachers' motivations for choosing science teaching as a career and their epistemological beliefs: Is there a relationship? *Journal of Turkish Science Education, 11*(1), 115-132.

LaTurner, R. J. (2002). Teachers' academic preparation and commitment to teach math and science. *Teaching and teacher education*, *18*(6), 653-663.

Lee, S. W. (2018). Pulling back the curtain: Revealing the cumulative importance of high-performing, highly qualified teachers on students' educational outcome. *Educational Evaluation and Policy Analysis*, *40*(3), 359-381.

Lee, S. W., & Mamerow, G. (2019). Understanding the role cumulative exposure to highly qualified science teachers plays in students' educational pathways. *Journal of Research in Science Teaching*, *56*(10), 1362-1383.

Liou, P. Y., Kirchhoff, A., & Lawrenz, F. (2010). Perceived effects of scholarships on STEM majors' commitment to teaching in high need schools. *Journal of Science Teacher Education*, *21*(4), 451–470.

Luehmann, A. L. (2007). Identity development as a lens to science teacher preparation. *Science Education*, *91*(5), 822-839.

Luft, J., Fletcher, S., & Fortney, B. (2005). Early Recruitment of Science Teachers: Promising or Problematic Strategy. *Science Educator*, *14*(1), 41-48.

Luft, J. A., Wong, S. S., & Semken, S. (2011). Rethinking recruitment: The comprehensive and strategic recruitment of secondary science teachers. *Journal of Science Teacher Education*, *22*(5), 459–474.

Martin, L. E., & Mulvihill, T. M. (2016). Voices in Education: Teacher Shortage: Myth or Reality?. The Teacher Educator, 51(3), 175-184.

Marso, R. N., & Pigge, F. L. (1997). A longitudinal study of persisting and nonpersisting teachers' academic and personal characteristics. *The Journal of Experimental Education*, *65*(3), 243-254.

Martin, L. E., & Mulvihill, T. M. (2016). Voices in Education: Teacher Shortage: Myth or Reality? *The Teacher Educator*, *51*(3), 175-184.

Meyrick, J. (2006). What is good qualitative research? A first step towards a comprehensive approach to judging rigour/quality. *Journal of health psychology*, *11*(5), 799-808.

Moin, L. J., Dorfield, J. K., & Schunn, C. D. (2005). Where can we find future K-12 science and math teachers? A search by academic year, discipline, and academic performance level. *Science Education*, *89*, 980–1006.

Morrell, P. D., Park Rogers, M. A., Pyle, E. J., Roehrig, G., & Veal, W. R. (2020). Preparing Teachers of Science for 2020 and Beyond: Highlighting Changes to the NSTA/ASTE Standards for Science Teacher Preparation.

National Research Council. (2010). Preparing Teachers: Building Evidence for Sound Policy. Washington, DC: National Academy Press.

National Science Teaching Association (2020). 2020 NSTA/ASTE Standards for Science Teacher Preparation. Retrieved from: https://static.nsta.org/pdfs/2020NSTAStandards.pdf

Newton, X. A., Jang, H., Nunes, N., & Stone, E. (2010). Recruiting, Preparing, and Retaining High Quality Secondary Mathematics and Science Teachers for Urban Schools: The Cal Teach Experimental Program. Issues in Teacher Education, 19(1), 21-40.

Neuendorf, K. A. (2016). *The content analysis guidebook*. Sage.

Nixon, R. S., Luft, J. A., & Ross, R. J. (2017). Prevalence and predictors of out-of-field teaching in the first five years. *Journal of Research in Science Teaching*, *54*(9), 1197-1218.

Olson, J. K., Tippett, C. D., Milford, T. M., Ohana, C., & Clough, M. P. (2015). Science teacher preparation in a North American context. *Journal of Science Teacher Education*, *26*(1), 7-28.

Partelow, L., & Baumgardner, C. (2016). Educator Pipeline at Risk: Teacher Labor Markets after the Great Recession. *Center for American Progress*.

Perda, D. (2013). Transitions into and out of teaching: A longitudinal analysis of early career teacher turnover (Unpublished doctoral dissertation). University of Pennsylvania, Philadelphia.

Rich, M. (2015). Teacher shortages spur a nationwide hiring scramble (credentials optional). *The New York Times*, *1*.

Sarason, S. B. (1974). The psychological sense of community: Prospects for a community psychology. Jossey-Bass.

Saxman, L. J., Gupta, P., & Steinberg, R. N. (2010). CLUSTER: University-science center partnership for science teacher preparation. *New Educator*, *6*, 280–296.

Schuster, D. (2013). In pursuit of sustainable STEM certification programs. *Journal of College Science Teaching*, *42*(4), 38–45.

Scott, T. P., Milam, J. L., Stuessy, C. L., Blount, K. P., & Bentz, A. (2006). Math and science scholars (MASS) program: A model program for the recruitment and retention of preservice mathematics and science teachers. *Journal of Science Teacher Education*, *17*(4), 389-411.

See, B. H., Morris, R., Gorard, S., Kokotsaki, D., & Abdi, S. (2020). Teacher recruitment and retention: A critical review of international evidence of most promising interventions. *Education Sciences*, *10*(10), 262.

Seebruck, R. (2015). Teacher quality and student achievement: A multilevel analysis of teacher credentialization and student test scores in California high schools. *McGill Sociological Review*, *5*, 1-18.

Shugart, S. S., & Hounshell, P. B. (1995). Subject matter competence and the recruitment and retention of secondary science teachers. *Journal of Research in Science Teaching*, *32*(1), 63-70.

Sorensen, L. C., & Ladd, H. (2018). The Hidden Costs of Teacher Turnover. *National Center for Analysis of Longitudinal Data in Education Research (CALDER) Working Paper*, (203-0918), 1.

Smith, M. H., & Trexler, C. J. (2006). A university-school partnership model: Providing stakeholders with benefits to enhance science literacy. *Action in Teacher Education*, *27*(4), 23-34.

Staudt, D., Risku, M., & Martinez, E. (2008). Science and mathematics alliance for recruiting and retaining teachers (SMARRT): Addressing the teacher shortage in at-risk schools. *Australian Journal of Teacher Education (Online)*, *33*(4), 55-66.

Sutcher, L., Darling-Hammond, L., & Carver-Thomas, D. (2016). A coming crisis in teaching? Teacher supply, demand, and shortages in the US. *Learning Policy Institute*.

Sutcher, L., Darling-Hammond, L., & Carver-Thomas, D. (2019). Understanding teacher shortages: An analysis of teacher supply and demand in the United States. *education policy analysis archives*, *27*(35).

Tai, R. H., Liu, C. Q., & Fan, X. (2007). Factors Influencing Retention of Mathematics and Science Teachers in Secondary Schools--A Study Based on SASS/TFS. *Science Educator*, *16*(2), 27-32.

Tillotson, J. W., & Young, M. J. (2013). The IMPPACT Project: A model for studying how preservice program experiences influence science teachers' beliefs and

practices. *International Journal of Education in Mathematics, Science and Technology*, *1*(3).

Tomanek, D., & Cummings, K. E. (1999). The use of secondary science classroom teaching assistant experiences to recruit academically talented science majors into teaching. *Science Education*, *84*(2), 212-227.

Torres, A. S. (2012). "Hello, goodbye": Exploring the phenomenon of leaving teaching early. *Journal of Educational Change*, *13*(1), 117-154.

U.S. Department of Education. (2005). No child left behind: A toolkit for teachers. Washington, DC: U.S. Department of Education Retrieved from https://www2.ed.gov/teachers/nclbguide/nclb-teachers-toolkit.pdf

Viadero, D. (2018). Teaching shortages: Many answers for a complex problem. *Education Week*, *37*(18), 4-5.

Wang, H.H. (2004). Why teach science? Graduate science students' perceived motivations for choosing teaching as a career in Taiwan. *International Journal of Science Education*, *26*(1), 113–128.

Weiss, E. M. (1999). Perceived workplace conditions and first-year teachers' morale, career choice commitment, and planned retention: A secondary analysis. *Teaching and teacher education*, *15*(8), 861-879.

Westerlund, Julie F., Radcliffe, Rich, A., Smith, Daniel A., Lemke, Maureen R., & West, S. S. (2011). Profiles of U.S. science teacher candidates: Safeguards amidst the gathering storm. *International Journal of Environmental and Science Education*, *6*(3), 213–227.

Wilson, S. M., Floden, R. E., & Ferrini-Mundy, J. (2001). *Teacher preparation research: Current knowledge, gaps, and recommendations: A research report prepared for the US department of education and the office for educational research and improvement, February 2001*. Center for the Study of Teaching and Policy.

Wilson, S. M., Bell, C., Galosy, J. A., & Shouse, A. W. (2004). "Them that's got shall get": Understanding teacher recruitment, induction, and retention. *Yearbook of the National Society for the Study of Education*, *103*(1), 145-179.

Worsham, H. M., Friedrichsen, P., Soucie, M., Barnett, E., & Akiba, M. (2013). Recruiting science majors into secondary science teaching: Paid internships in informal science settings. *Journal of Science Teacher Education*, *25*(1), 53–77.

Zamarro, G., Camp, A., Fuchsman, D. & McGee, J.B. (2021). *How the pandemic has changed teachers' commitment to remaining in the classroom*. Brown Center Chalkboard. https://www.brookings.edu/blog/brown-center-chalkboard/2021/09/08/how-the-pandemic-has-changed-teachers-commitment-to-remaining-in-the-classroom/