# Scientists to Teachers: Considering Careers as Science Teachers

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Shortages of STEM teachers have presented challenges to school employers for decades. Additionally, universities are tasked to produce science teachers of better quality, equipped in both content and pedagogical strategies. Undergraduate STEM majors with no prior inclination toward teaching were strategically selected to receive pedagogical training and structured opportunities to experience science teaching. Perceptions of teaching science, teaching self-efficacy, and interest in science teaching careers were measured before and after completion of the program using the STEBI-B instrument. Results were counterintuitive but informative. The teaching self-efficacy scores of participants decreased after instructional experiences with younger students.

## Introduction

For decades, quality science education has been recognized as important for economic growth (Drori, 1998; Barro, 2013), a citizenry with the capacity for rational, evidence-based decisions (Heuer, 2015), and for producing scientists needed for resolving issues from health to environmental protection (Huff, 2016). Over an equivalent span of time, STEM teacher shortages have been noted (Hutchison, 2012; Aragon, 2016; Sutcher et al., 2016; Dee and Goldhaber, 2017). The gravity underlying efforts to curb the falling tide of proficient science educators goes far beyond simply filling spaces in classrooms.

Mikeska, et al. (2017) reported that instructional practices of science teachers which allowed student-centered engagement in investigations led to improved student outcomes. Both student achievement scores and attitudes toward science were highest among students who were allowed by their teachers to draw conclusions on data derived from their inquiry activities (Jiang & McComas, 2015). Recognizing the growing importance of functional scientific literacy in society, advocacy for a new paradigm of science education has been underway. Short et al. (2022) contend that societies have swiftly progressed from the Information Age to an “Age of Inference” since the turn of the century, and that this progression requires more sophisticated reasoning capabilities to process and make sense of the deluge data/information at our disposal. McConnell et al. (2022) suggested that it is crucial for teachers to remain learners that are well-equipped in their use of inferential reasoning abilities. McComas (2016) argued that the most important goal of science teaching is for students to understand how science develops, generates, tests, and validates scientific knowledge, students must appreciate the strengths and limits of the scientific enterprise while Short (2022) lamented that too many teachers value conclusive answers over the process of sensemaking. Better understandings of the tentative nature of science (NOS) among teachers are imperative for improvements in science education. Henson (2022) advocates for scientists to be better educators and educators to think of themselves as scientists; however, he acknowledges that many preservice students have a poor understanding of (NOS). Misconceptions of NOS limit teachers' effectiveness in providing authentic inquiry-science opportunities that build necessary analysis and decision-making skills for the Age of Inference (Short et al., 2022).

A major reform and paradigmatic, conceptual shift in teaching and learning accompanies the Next Generation Science Standards (NGSS) emerging from The National Research Council's Framework for K-12 Science Education (NRC, 2013). The NGSS integrates instruction in the three dimensions of: 1) science and engineering practices; 2) disciplinary core ideas, and; 3) cross-cutting concepts (NGSS Lead States, 2013). The importance of providing students genuine practices of scientists is well-established (Schwarz et al., 2017). While Harris et al. (2015) stated that the NGSS would result in better instruction and increase interest and performance in science, adapting to the new frameworks for science education has not been easy for many educators (Quinlan, 2018). In this study, we not only attempted to recruit potential teacher candidates from science majors, but we also introduced them to a new paradigm in science pedagogy with which even successful science students are unfamiliar. Our participants, while grounded in science content, were not generally knowledgeable about effective teaching strategies in science. Undergraduate students pursuing degrees in the science disciplines and graduates in early career phases are immersed in the vital mindset of NOS during their lab and field research work. Relatively few, however, consider science education as a first career choice as a range of other, potential career options that may be more lucrative presents a major obstacle (Angus-Cole, 2021).

Traversing the often-wide chasm between the language and culture of professional science and that of education can leave career changers with self-doubt, feelings of inadequacy, and frustrations even when accomplished in their respective science disciplines. Paving the way for transitioning scientists requires greater understanding of their emotional responses to new career landscapes and better supports as they evolve pedagogically. Understanding teacher agency and the factors that promote it is essential for meaningful education. (Biesta et al., 2015). Balgopal (2020) suggests that members of a professional communities, such as science educators, should experience the feeling of being valued, and that this may help retain newer teachers in the field. Attempts were made to provide these professional communities with networking among the STEM student participants, university faculty, and seasoned K-12 teaching staff.

## Methods

This study was conducted as part of a project funded by a Tennessee Innovation in Preparation (TIP) Grant award by the Tennessee Department of Education. The study was a collaboration between the College of Education and the College of STEM at a mid-sized university in the southeastern United States. The purpose of the project included: 1) exploring an alternative route for science majors to finish their undergraduate majors and obtain a provisional teaching license while completing a Master of Arts in Teaching (MAT); 2) creating a recruiting strategy and teaching assistant (TA) program to increase student interest and self-confidence in teaching as well as improve attitudes toward the profession; and 3) creating a sustainable science outreach program and teaching assistant (TA) opportunities with the STEM Scouts after school science enrichment program and create Science Friday activity days for interested school districts. The research focus in this study was on changes in the TAs' attitudes toward science teaching, self-efficacy in their science teaching abilities, and their intentions to pursue careers in science education. A mixed method design consisting of both the STEBI-B survey questions and four open-ended, free response questions was used.

Paid stipends, offered through the grant, were awarded to fund sixteen teacher assistant (TA) positions within the departments of biology and chemistry. The TAs received content area training and orientation, facilitated by the appropriate science department, for working with undergraduates enrolled in introductory laboratory courses. In addition to the TA laboratory positions, opportunities for students to interact with children in grades K-12 were afforded. Each TA was required to participate in outreach experiences with the STEM Scouts® (https://stemscouts.org/) lab groups. Lastly, they were to help develop and deliver a hands-on "Science Fridays" program that offered for local school field trips to the university and teaching experiences in local school districts.

Prior to any pedagogical training and participation in K-12 science activities, TAs were administered a survey consisting of two sections. The first section included the Science Teaching Efficacy Belief Instrument (STEBI), a widely accepted and validated instrument developed by Riggs and Enochs (1990). The second section of the survey consisted of qualitative, open-ended questions about the students' intentions toward pursuing a career in science teaching. Pre and post data were collected from all TA participants, in the fall semester and spring semester, respectively. The STEBI-B instrument includes two subscales: 1) questions assessing the participants' Science Teaching Outcome Expectancy (STOE), a measure of the student's belief that their teaching will have a positive effect for their students); and 2) questions assessing the participants' Personal Science Teaching Efficacy (PSTE), a measure of the student's belief that they can teach science effectively; Enochs & Riggs, 1990; Morrell & Carroll, 2003). Each of the two subscales, and the entire instrument, have been validated and deemed reliable in the original and subsequent studies (Saka, Bayram, and Kabapmar, 2016). The maximum scores for the STOE is 50 and 65 for the PSTE.

Students took the same survey prior to two pedagogical workshops in the fall semester and teaching experiences (the pretest), and during the final week of the spring semester after training workshops and opportunities to plan and deliver lessons (the posttest). Independent sample t-tests were used to determine the significance of the pre-post difference. The effect size was quantified using the Cohen's d statistic (Cohen, 1988). The null hypotheses ($H_0$) were:

1) No significant difference between pretest and posttest PSTE scores exists.

2) No significant difference between pretest and posttest STOE scores exists.

The primary purpose of the open-ended free response survey questions was to identify personal perspectives about teaching, inquiries about the outcomes of teaching experiences, self-identified qualities of "good" teachers, concerns about teaching as a profession, and supports needed from the university. Each open-ended survey question was developed for a specific reason with hopes of gaining insight into the TA perspectives, thoughts, and feelings about the teaching profession. The questions and rationale for development of each question are listed below.

1. What are you hoping to learn from this experience as a TA involved with this grant experience?
   Rationale: The researchers hoped to glean the individual perspectives on what their desires were from this grant experience.
2. What qualities do you possess that would make you a good teacher?
   Rationale: This question was developed as a qualitative way to provide data to support and triangulate the STOE portion of the STEBI-B. This question encouraged the TAs to examine personal self-images that each possess that they consider qualities of good teachers.
3. What are your concerns about teaching?
   Rationale: This question was developed to determine any preconceived notions that the TA's may hold about teaching.
4. What can the university do to support your career decisions?
   Rationale: This question was developed as a means to provide the researchers with information needed to support student success, regardless of the profession selected.

## Limitations

Limitations of the study consisted of a small sample size and time constraints. Sixteen participants were selected, but one could not continue in the study. With 15 participant TAs completing their duties but only 14 respondents to the surveys, we caution against generalizing the results presented beyond this specific study population sample. Time allowed for only two pedagogy workshops during the course of the program. Findings from this study should be considered preliminary but should generate interest in further research.

## Results

The mean scores on the pretest and posttest for PSTE were in the mid-range (42.59 of 60, and 35.14 of 60), and there was a significant difference in means with personal teaching self-efficacy declining over the course of the program (Table 1). The first null hypothesis was rejected. The effect size is interpreted to be large with Cohen's d calculated to be -2.21 and -0.74 as the r-based effect size.

***Table 1.***
***t-test results comparing scores on personal science teaching efficacy***

| Test | n | Mean | SD | t-cal | t-crit | df | P | Decision |
|---|---|---|---|---|---|---|---|---|
| Pretest | 14 | 42.29 | 3.58 | 8.59 | 2.16 | 13 | <0.0001 | Reject |
| Posttest | 14 | 35.14 | 2.85 | | | | | |

Similar to results for the PSTE, the mean scores on the pretest and posttest for the STOE subscale of the STEBI-B were in the mid-range (33.86 of 50, and 27.57 of 50), and there was a significant difference in means with STOE scores declining over the course of the program (Table 2). The second null hypothesis was rejected. The effect size is interpreted to be large with Cohen's d calculated to be -4.78 and -0.92 as the r-based effect size.

***Table 2***
***t-test results comparing scores on science teaching outcome expectancy***

| Test | n | Mean | SD | t-cal | t-crit | df | P | Decision |
|---|---|---|---|---|---|---|---|---|
| Pretest | 14 | 33.86 | 1.65 | 4.00 | 2.16 | 13 | 0.0015 | Reject |
| Posttest | 14 | 27.57 | 0.86 | | | | | |

Given the benchmarks on effect size provided by Cohen's d statistic (Enzmann, 2015), the effect sizes for both PSTE and STOE may be considered large. While not an intended or expected outcome in a program designed to recruit teachers from the science majors, it may be, nevertheless, very informative.

The responses to each of the four questions were coded using a grounded theory approach (Strauss & Corbin, 1998). This procedure allows theories and codes to emerge from the data, enabling the researchers to gain insight about individual TA perceptions regarding self-image, teaching, and support needed; the outcome of this data was intended to guide the researchers in meaningful interpretations. Researchers independently read all TA free responses to glean common interpretations, resulting in stable codes that emerged from the questions. This technique resulted in a high degree of consistency, thereby establishing the codes in an independent manner. Representative participant statements that aligned with each code resulted in an interpretation for each code (Table 3).

***Table 3***
***Teacher assistants' free responses***

| Code | Representative Statements | Interpretations |
|---|---|---|
| Knowledge of Teaching | "I hope to learn how to teach."<br>"I am hoping to gain insight into how one should operate and guide a class."<br>"I hope to gain teaching and leadership skills." | Seeking pedagogical knowledge |
| Student Success | "I want to learn how to help students succeed."<br>"I want to learn effective ways to interact with students."<br>"I want to get practice explaining science concepts in ways that many people can understand." | Student learning is of the upmost importance |

| | | |
|---|---|---|
| Qualities of Teachers | "I am organized in my planning and I'm very empathetic to people in general." "I am patient as well as understanding." "I can present information in a very straight forward and simple way to understand." | Positive self-image of teaching abilities. |
| Concerns about Teaching | "I am concerned about evaluations and all the testing that takes place." "Behavior issues with students." "I wouldn't like the strict rules about how and when subjects are taught." "Teachers are not paid enough." | Societal issues related to the teaching profession |
| University Support | "So far this program is a step in the right direction." "Continue to provide opportunities that enable students to learn the abilities to be successful in future careers." "I think career options and opportunities available to students in courses that would pertain to those careers." "Continue to offer programs such as this that allows people to dip their toes in the water with different career options." | Career support and specific professional guidance. |

The results of the codes and interpretations are consistent with other research in the field of teacher preparation. Hutchison (2012) suggested that college-age students often desire to enter the teaching profession without knowing how to start this process, and career professionals tend to have similar questions about how to enter the teaching profession. Other researchers have found similar uncertainties about careers in college science majors. Science teacher educators frequently hear comments from college students such as, "I am graduating this semester with an undergraduate degree in chemistry and I don't have a job. I have considered teaching; but, I don't know where to start" (Hutchison, 2012). Comments like that above indicate not only a desire to teach students but also that more obvious pathways for entering the teaching profession are needed. The links and associations between the codes, representative statement, and the interpretations were consistent across all TA comments. These representative statements both previous studies and ours clearly note that additional support for university students in STEM areas is needed.

## Discussion

The implication from this study is that STEM majors, while grounded in science content, have little experience with former or current instructors modeling pedagogical strategies that are effective for K-12 students. This study focused on introducing pedagogical strategies and providing teaching opportunities rather than increasing science content knowledge. Significant differences were found in both STOE and PTSE scores on pretests and posttests; however, the changes were in a negative direction suggesting that the TAs' perceptions of a career in science teaching were less favorable and their personal self-confidence in their teaching abilities waned.

As counter-intuitive as the results may appear on the surface, some cogent arguments can be made for the disillusionment college science majors experienced when first exposed to the complexities of inquiry-based science education.

A similar study focused on providing more science content knowledge to improve STEBI-B scores also failed to produce positive changes. Results from Cervato and Kerton (2017) demonstrated that the activities specifically designed to increase elementary education majors' STSE had no significantly higher impact on their personal self-efficacy than a simple hybrid course. Likewise, they found no significant difference between their students' understanding of science teaching expectations (STOE) before and after the course, no matter what activity they worked on. Cervato and Kerton (2017) continued by suggesting a comparison of the STSE gains in science content courses taught by science education faculty with existing studies focusing on science courses taught by content area faculty as they speculated that science education faculty would naturally model effective science teaching practices and that this might positively impact students' STSE.

Content knowledge and pedagogical mastery are the most significant factors in teaching self-efficacy (Bautista, 2011). Studies have shown that the science self-efficacy of preservice elementary teachers, many of whom have taken very few science courses since high school, is low (Bleicher & Lindgren, 2005; Tosun, 2000). This was not the case, however, with our targeted students. Interest, content proficiency and self-images related to teaching in general was high. As evidenced in the open-ended survey responses, many TAs felt that they possessed the qualities of a teacher prior to beginning the study. This was the prime reason these students were selected as TA for this study. With a high initial self-efficacy and high content knowledge, the significant difference in the negative direction is understandable. As the TAs experienced teaching opportunities and extensive time with undergraduate and K-12 students, the realization that teaching was not a simple task became obvious.

Many of the TAs had post-survey comments such as, "Will I be able to communicate effectively with the students" and "Many of the students have low motivation, and this deters me from the profession." Along with these student concerns, there were expressed concerns about the profession as a whole, such as, "There is a general lack of respect for teachers," and "Will I be able to maintain control of my classroom." These comments help to provide evidence to support the complexities of teaching.

## Conclusions and Recommendations

Given the results of this study, there are multiple recommendations that can be drawn that advances the idea of recruitment and support of future STEM teachers. From this study, we realize that strong scientific content knowledge and high self-efficacy are extremely important, but these two elements are only a small part of being a confident and proficient STEM teacher. The recommendations for STEM teacher recruitment and support is threefold:

1) university support for undecided STEM students to "experiment" in education;
2) enhanced and continued collaboration between colleges of education and colleges of STEM; and
3) vibrant partnerships with local school districts to bolster and encourage budding STEM teachers.

As evidenced in our open-ended surveys, undecided STEM students have a desire for greater support from the university. Such support could include the following:

1) faculty encouraging university involvement by inviting personnel from the university career center to work directly with students identified as possible STEM teachers;
2) faculty mentors may be assigned from the college of STEM and education to encourage these students through professional development opportunities used to encourage and inform these students;
3) teaching assistantships and scholarships related to teaching careers should be offered to these students.

Additionally, providing "hands-on" peer teaching experiences in university STEM classes will be beneficial in shaping the futures of these undecided students. University involvement at the grass-roots level has the potential to effectively produce an increased interest in STEM teaching.

Collaboration between colleges at the university is essential to increase the number of students interested in becoming STEM educators. As students indicated in the surveys, "I have an interest in teaching, but I am not sure what is needed to become a teacher." As faculty from colleges of STEM and education work together, STEM students with undecided futures may be guided and supported into the teaching profession. College of education faculty may meet with groups of STEM students and provide program and licensing information as well as guidance to the courses needed for obtaining a teaching license. Joint professional development opportunities may be offered by faculty from both colleges to interested STEM students. Collaboration between colleges within a university is key to successful selection, training, and support of undecided STEM majors who are interested in the teaching profession. Lastly, partnerships between local school districts and STEM majors could support these students. Undecided STEM students, prior to a commitment in education, could be paired with successful STEM teachers, allowing early observations in classrooms and labs, opportunities for tutoring students, and shadowing of successful teachers.

Suggestions for further research includes identifying key influences that led individuals first to science fields ranging from biology, chemistry, geology, medicine, and physics and, then, into a variety of positions in science education. Working with graduate students in science education, an open exploration of STEM majors is underway to identify common attractions to education as well as deterrents to the career. This continuing study will help identify both personal and environmental variable for expanded investigations. The sharing of personal trajectories should help facilitate networking for the development of research teams to examine different facets of the "scientist to educator" transition and identify strategies for lowering barriers.

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