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## INCREASING THE STEM TEACHING PIPELINE

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## **Increasing the STEM Teaching Pipeline**

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### **Abstract**

Tennessee Tech University's – STEM Majors for Rural Teaching (TTU-SMaRT) Noyce Scholarship Program<sup>1</sup> aims to produce highly qualified teachers of mathematics, physics and chemistry to help address the high demand for STEM educators nationally. Over 40 STEM majors have participated in the Early Teaching Experience internship and 26 STEM majors have so far been supported by Noyce scholarships. We share lessons learned over the past 9 years regarding key partnerships, successful recruitment, and programming.

### **Background**

Nationwide, there have been many recent calls for an increased emphasis on STEM education (see, for example: National Research Council, 2011; National Science Board, 2011). Tennessee's recently issued strategic plan for preK–12 STEM education (Tennessee Department of Education, 2018) calls for the integration of a coordinated program of standards-based STEM education through all grades. Accompanying these calls is a recognition that there is a shortage

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of highly-trained STEM teachers (United States Department of Education, 2017), capable of delivering effective instruction. Rural areas, such as the Upper Cumberland, face additional challenges in recruiting and retaining highly qualified teachers in the fields of math and science, which can result in sub-par student performance (Alliance for Excellent Education, 2010).

This situation is exacerbated by increasing rigor in recently adopted high school standards in Tennessee. These require that all students take four high-school math courses for graduation, including a higher-level course, such as trigonometry or calculus, as well as a three-course high school science requirement, which must include Chemistry and/or Physics. In 2016, a dedicated STEM pathway was introduced, adding a fourth, more advanced, science course, such as AP Biology, Physics, Chemistry, or Environmental Sciences. Together, these new requirements are resulting in a large increase in the number of students taking higher-level math and science courses with no increase in qualified teachers to deliver these courses.

### **Overview of TTU-SMaRT Program**

TTU-STEM Majors for Rural Teaching (TTU-SMaRT) is funded by the National Science Foundation as a Track 1: Robert F. Noyce Scholarship Program. It is a collaboration between Tennessee Tech University (TTU) and six high-need local education agencies (LEAs): Fentress County, York Institute, Jackson County, Overton County, Pickett County, and Putnam County. The central goal of TTU-SMaRT is to support and graduate 25 job-ready, highly-trained teachers in high school mathematics and science, desperately needed in the rural Upper Cumberland region. TTU-SMaRT supports paid internships and generous scholarships for Math, Science, and Engineering majors while they complete their STEM degree and also obtain licensure to teach high-school Math, Physics, or Chemistry. Noyce scholars/stipend recipients complete their

intended STEM discipline degree and earn teacher licensure through education programs taken either as undergraduates or post-baccalaureate (post-bac) students.

Eligible majors are:

- Mathematics
- Physics
- Chemistry
- Chemical Engineering
- Mechanical Engineering
- Civil and Environmental Engineering
- Electrical and Computer Engineering
- Computer Science

Program features include an early teaching experience (ETE), Noyce Scholarship, teaching internship, and induction year support. Undergraduates are eligible for scholarship support for up to two years (6 terms, including summers) while post-bac students are eligible for one year (including 2 summer terms). TTU provides a large pool of over 2,500 STEM majors to draw from, most of who are majoring one of the many programs in the College of Engineering. Part of the recruitment effort offers students an early teaching experience (ETE) to explore whether teaching is a career path they wish to pursue and to take an introductory education course. The program also leverages the high quality of TTU teacher education programs, resources offered by the TTU STEM Center, and the close collaboration that exists between TTU's Colleges of Arts and Science, Engineering, and Education. The partner LEAs assure appropriate mentoring of clinical experiences and are made aware of program graduates so they have first opportunities to recruit and hire them. First-year teachers are also provided with

mentoring and support for professional development, and remain members of the Noyce community beyond their induction year.

### **Early Teaching Experience**

Successful applicants can earn a stipend while they gain up to 200 hours of experience in a variety of STEM education settings involving different aspects of teaching. Much of this can be done through outreach programs offered by the TTU STEM Center, but other opportunities are also available. At least 120 hours of this experience is with K–12 students. The remaining 80 hours can be in settings where the candidates interact directly with inservice STEM teachers through participation in teacher professional development training, professional learning community meetings, and/or as teaching assistants in classrooms. It has been shown that giving students an early experience in an instructional setting is an effective recruiting tool (AAAS, 2012; Lee & Nason, 2013, Sandifer & Brewé, 2015). Further, these types of experiences are an effective way of targeting STEM majors that might not otherwise have considered a career path in K–12 STEM education.

### **Noyce Scholarship**

Recipients can receive generous (full) scholarship support for up to three years (of which one can be post-baccalaureate) while they both complete their STEM degree and work toward obtaining teaching licensure in Mathematics, Physics, or Chemistry. In most cases this licensure is obtained after a one-year post-baccalaureate program of study combined with teaching residency. It is important to note that for each year of Noyce scholarship support, the recipient must commit to two years of teaching in a high-need school district in the United States—preferably a rural school in the Upper Cumberland area of Tennessee. If this commitment is not fulfilled, the scholarship reverts to a loan that must be repaid.

## **Teaching Internship**

Pedagogical content knowledge (PCK) (Shulman, 1987) combines deep content knowledge, knowledge of standards and curriculum, and an understanding of how students learn. By its very nature, much of PCK can best be developed in the context of instruction (Evens, Elen, & Depaepe, 2015) and it has been shown that teachers with highly developed PCK are more likely to be effective in their instruction (Van Driel, Verloop, & De Voss, 1998; Gess-Newsome & Lederman, 2001). To begin developing their PCK, and so enhance the effectiveness of their teaching skills, scholars are supported while they engage as lead instructors in a residency at the STEM Center. During this residency, Noyce scholars enhance their teaching skills by taking a more prominent role in various STEM Center outreach programs. They collaborate with STEM Center staff, TTU faculty, and experienced K–12 teachers in designing, implementing, and co-leading workshops and other learning opportunities for K–12 students and the general public. At the same time they work with the Noyce program staff to examine theoretical and practical aspects of teaching in the STEM disciplines.

## **Induction Year Support**

A study of teachers in Tennessee (Ronfeldt, Brockman, & Campbell, 2018) has shown that preservice teachers who are mentored in their clinical practice by more effective cooperating teachers themselves become more effective teachers. Further, it is well-known that beginning teachers need support and encouragement (Anhorn, 2008), and that well-designed mentoring programs can improve retention rates for new teachers (Darling-Hammond, 2000). Finally, a recent meta-analysis (Darling-Hammond, Hyler, & Gardner, 2017) has shown that among the shared features of effective teacher professional development programs are those of supporting

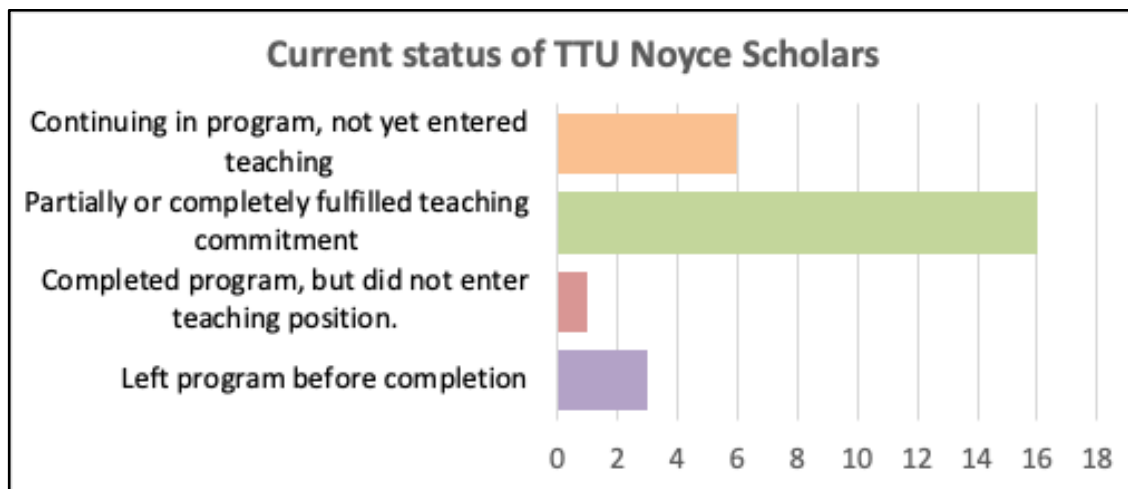
collaboration, exhibiting models of effective practice, providing coaching and expert support, offering feedback and reflection, and a sustained duration.

TTU-SMaRT works with partner K–12 school districts to help newly-licensed Noyce graduates find a suitable placement for their first year of full-time teaching. During this first year, Noyce graduates are supported to return to TTU for dedicated professional development, become members in appropriate professional STEM education organizations, and travel (with their mentor) to professional STEM education meetings.

### TTU-SMaRT Data

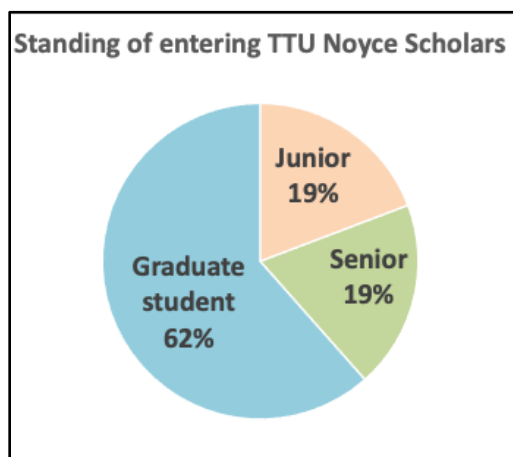
To date, the program has engaged 43 students in an Early Teaching Experience (ETE), of whom 13 were successful in applying for Noyce scholarship support. This represents 50% of the 26 students who have so far been supported with scholarships, suggesting that the ETE is an effective recruiting strategy. The current status of the 26 scholars supported is shown in Figure 1. Of the 16 scholars who have already entered teaching, 12 have either already fulfilled their commitment or intend to do so. The other four left the teaching profession before doing so.

**Figure 1:** *Current Status of TTU Noyce Scholars*



Over 60% of our Noyce Scholars entered the program as graduate students after completing their undergraduate degrees (see Figure 2). Of those who joined as undergraduates, many did so in their final semester and went on to complete the program as graduate students. Thus, approximately 80% of our scholars have obtained, or are currently pursuing, a graduate degree in education while obtaining licensure.

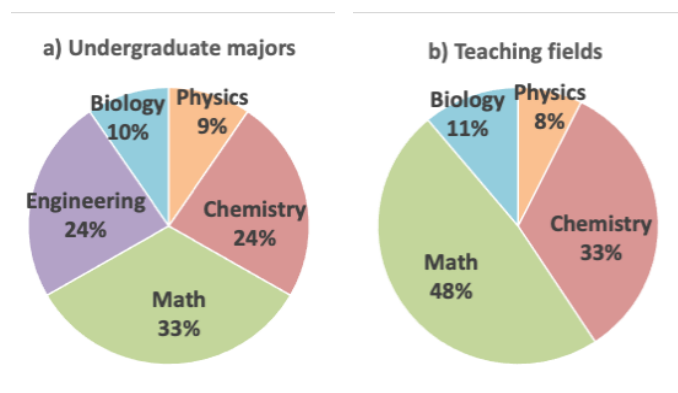
**Figure 2:** Standing of Entering TTU Noyce Scholars



While the vast majority of undergraduate STEM majors at TTU are in one of the many programs in Engineering, Figure 3a shows that the distribution of majors among Noyce scholars is more even. The teaching fields in which the scholars have obtained, or are seeking, certification is heavily concentrated in Mathematics and Chemistry (see Figure 3b)). This is

partly because most engineering majors seek certification in Math. Also, those in all STEM fields sometimes seek a second certification to make themselves more “employable,” and that is usually in Math or Chemistry.

**Figure 3:** Distribution of Noyce Scholars by Major and Licensure





The original goal of the TTU-SMaRT program was to graduate 25 highly trained, job-ready teachers in STEM disciplines. While the data indicates that we are on target to achieve this goal, the program has gradually evolved in response to trends emerging from the data summarized above. For example, the large proportion of scholars completing the program as graduate students indicated that this would be a fruitful area for recruitment. In addition, students gaining certification in more than one STEM discipline was not a feature we anticipated, but proved attractive to rural schools that may not have enough enrollment to justify a pure Physics or Chemistry teacher. These emerging trends, as well as other lessons learned (discussed in the next section) have meant that the program has had to be adaptable to achieve its goals.

### **Lessons Learned from TTU-SMaRT**

During the operation of the TTU-SMaRT program to date, important lessons have been learned with regards to key partnerships, successful recruitment, and programming. Just like adapting to the trends emerging from the data, these have been incorporated into the program as they emerge, and are described in more detail below. We suggest that most of these would be important elements to include in any such program, though some are specific to the particular circumstances at TTU.

#### **Lessons Learned: Key Partnerships**

**Oakley STEM Center** – From its inception the TTU-SMaRT program has had a close partnership with the Millard Oakley STEM Center at TTU. One major element of the Center's mission is to facilitate outreach programs for K–12 students. Helping to facilitate these programs allows ETE interns to gain experience in an instructional setting under the supervision of Center staff and TTU faculty. Noyce scholars also participate in a residency at the Center, during which they take a leadership role in these same outreach programs, working with Center staff to

develop and lead standards-based activities. In this way, scholars further develop their skills in designing and delivering standards-based, inquiry-focused instruction to groups that model their future classes. Scholars report that their STEM Center residencies have provided them with valuable opportunities that were not otherwise available in their programs of study, particularly in the area of classroom management, and also being able to develop, field test, and revise their own lesson plans without feeling under pressure to “get it right” the first time.

**Office of Teacher Education** – The TTU College of Education and the Office of Teacher Education (OTE) have established programs in secondary education that reflect current best practices in teacher education. However, current enrollment is not enough to meet the need for teachers in the targeted programs in the rural Upper Cumberland region. TTU-SMaRT addresses this issue by helping create a financially-viable pathway to teacher licensure for STEM majors and graduates. Also, since many Scholars enter the profession on a job-embedded license (which bypasses the requirement for student teaching), they need additional mentorship and support (particularly with regards to planning and classroom management) beyond the building-level support we provide in the induction years. OTE Staff assist in identifying qualified mentors in regional schools to serve in that capacity. They also play a key role in referring graduate students (with STEM undergraduate degrees)—who apply to post-baccalaureate initial licensure and job-embedded licensure programs—to us to discuss whether they can benefit from Noyce support.

**Advising Centers and Student Organizations** – Professional advisors in the TTU Student Success Centers (advising centers) and faculty advisors in relevant departments help guide students as they navigate post-secondary study. By collaborating with the academic advisors for STEM majors across campus, TTU-SMaRT has been able to market the program to

students who might otherwise have been overlooked as potential Noyce Scholars. In a similar vein, coordination with relevant student organizations and clubs has enabled the program to directly address groups of relevant students. In particular, working with the Leona Lusk Officer Black Cultural Center has enabled us to directly target minority recruitment.

### **Lessons Learned: Successful Recruitment**

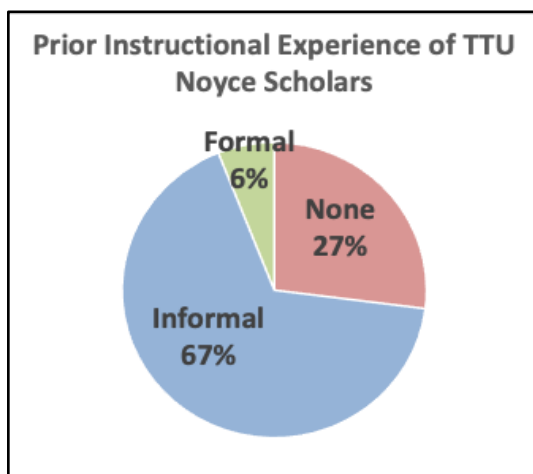
**Targeted Recruitment** – A broad recruiting drive inviting students to informational meetings through flyers/brochures was largely ineffective, whereas personal contacts, especially among participants and their peers, was a much better means of recruitment. A survey of program participants suggested that more targeted recruiting strategies would be more effective. As a result, four strategies have been identified to target potential Noyce Scholars: (1) a formal partnership was established with TTU's Advisement and Retention Services to work directly with advisors of STEM undergraduates to market the TTU-SMaRT ETE opportunities and Noyce Scholarships. Two personalized emails, announcing the opportunities and inviting them to informational meetings, are sent to advisors and shared and forwarded to all STEM majors each semester; (2) a personalized email is sent to graduating seniors in qualifying disciplines toward the end of their final semester; (3) a formal partnership was established with TTU's Crawford Alumni Center to reach out to more than 22,000 TTU alumni with STEM majors to seek potential career changers for Noyce scholar opportunities; and (4) a marketing/advertising presence has been established on the Oakley STEM Center's web pages and digital signage to feature the TTU-SMaRT program.

**Job-Embedded Licensure** – As designed, TTU-SMaRT aimed recruitment at undergraduate and graduate STEM majors to encourage them to consider the STEM teaching profession. We learned, however, that a pool of candidates who needed support were those

seeking licensure through a job-embedded route (versus the typical initial licensure route). The desperate regional need for high-quality STEM teachers resulted in several of our scholars being recruited on short notice (from STEM professions) by LEAs with the stipulation that they pursue a job-embedded license. It was essential to be flexible in how these students could complete teacher licensure requirements while teaching full time, since each individual had different circumstances. TTU-SMaRT was able to support these teachers with scholarships to obtain licensure and also provide financial support to mentor teachers in the induction year so that novice (job-embedded) teachers had an assigned mentor with whom they could plan and learn, but also attend professional education conferences to improve their teaching practice.

**STEM Majors Teaching Experience** – Another candidate pool we learned to target for recruitment was STEM majors who had already gained some informal or formal instructional experience. An analysis of our Noyce Scholars showed that more than two thirds (see Figure 4) of the students had already engaged in some level of informal teaching (e.g., peer tutoring, teaching small groups at church, serving as teaching/learning assistant in undergraduate labs) prior to choosing to obtain licensure in a STEM area.

*Figure 4: Prior Instructional Experience of TTU Noyce Scholars*



Thus, it seemed that targeting students already engaged in such instructional experiences was a natural fit for the program. However, it is notable that 27% of Noyce Scholars chose the teaching profession with no prior instructional experience.

### **Lessons Learned: Programming**

**Value of a thriving Noyce Community** – Our experiences have shown that a thriving community of Noyce participants is vital for mutual support and program health. While it took time to establish such a sense of community in the TTU-SMaRT program, the effort invested has proved worthwhile. Monthly daytime and evening meetings are open to ETE interns, scholars, program graduates (including those beyond their induction year), and mentor teachers. All are encouraged to bring guests, and meetings are structured to foster social interactions, emphasize program requirements and opportunities, and discuss topics in teaching and learning.

**Importance of Program Manager/Facilitator** – Having a dedicated and efficient program manager/facilitator is critical to establishing a thriving Noyce community. Such a person must be a good communicator and be well organized in order to keep track of the various moving parts of the program. Detailed record keeping is essential, with the program manager keeping records of scholarships awarded, and tracking and documenting how scholars are progressing toward fulfilling their teaching requirements. Developing mutually acceptable protocols by which the program communicates scholarship awards and tracking information with the TTU offices of Financial Aid and Business are critical.

**STEM Center Teacher Development** – Since the TTU STEM Center also serves as a regional hub for K–12 teacher professional development (PD) programs, there are numerous opportunities for ETE interns and Noyce Scholars to interact with practicing STEM teachers. TTU-SMaRT originally leveraged these PD opportunities as venues for scholars to obtain

ETE/internship hours and earn a stipend as a paid helper/assistant of PD instructors. However, it was soon realized that, in addition to helping to facilitate these programs, allowing the Scholars opportunities to participate as teachers in the PD relevant to their own intended teaching area, positioned them to learn more (earlier) about best practices and how they could be implemented in STEM classrooms. In this context, they are also able to interact and network with practicing teachers in a more informal environment, which they also reported as being very valuable. In addition, by participating in these programs, the Noyce Scholars become full members of the STEM Center User Group before they enter their first teaching position. Thus, more schools become aware of these resources and are able to take advantage of them.

### **Lessons Learned: Summary**

It is important for a program such as this to be adaptable. While our original plan seemed reasonable, the program had an extremely slow start. This was mainly because we were wrong in thinking many students would respond to a broad, campus-wide, recruitment drive. Instead, realizing that personal contact was being more effective, we changed to a more targeted recruitment strategy that took more effort, but was much more fruitful. As the program grew, data on participants further informed these efforts. Feedback from our participants also helped us realize that promoting opportunities for interaction with practicing teachers was very valuable. Not realizing how attractive our Noyce Scholars would be to area schools, we also had to adapt to deal with a significant fraction pursuing job-embedded licensure, working with the Office of Teacher Education to facilitate suitable programs of study. While not an adaptation, it also became clear that a thriving Noyce community was vital to the program, and that, in turn, depended heavily on having an enthusiastic and efficient program manager.

Finally, it is important to note that while the anticipated benefits of the TTU-SMaRT program were originally envisioned as one-directional (stipend/scholarship support and more generally to grow the STEM teaching pipeline at large), it was unanticipated that Tennessee Tech and its partners would receive benefits beyond those gleaned by increasing the number of high-quality STEM teachers in the region. Above all, the partnership with the STEM Center has provided broader impacts. While instructional opportunities for program interns and scholars were the original motivation for this partnership, by having a reliable pool of Noyce participants to draw on, the Center is able to offer more, and higher quality, outreach opportunities to area schools and the rural regional community than it otherwise could. Lessons developed by scholars have contributed to a “library” of standards-based activities that have also broadened the scope of what can be offered. In addition, having Noyce scholars entering their first teaching position already being members of the regional STEM teacher community and cognizant of the resources and support the STEM Center can provide enables more schools to take advantage of them. These benefits are both encouraging and motivational to continue in our efforts.

### **Conclusion**

Tennessee Tech University’s – STEM Majors for Rural Teaching (TTU-SMaRT) Noyce Scholarship Program aimed to produce 25 highly-qualified teachers of mathematics, physics and chemistry to help address the high demand for STEM educators regionally and nationally. TTU-SMaRT has exceeded that goal by providing stipends to over 40 STEM majors to participate in Early Teaching Experiences and by awarding scholarships to 26 STEM majors to date; funding is ongoing. By sharing the lessons learned over the past 9 years regarding key partnerships, successful recruitment, and programming, we encourage others to learn from our successes (and non-successes) to enhance and improve their efforts at increasing the STEM teaching pipeline.

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