Recruiting Future Physics Teachers through a Field-Based Summer Enrichment Program

Marissa E. Bellino
The College of New Jersey
Department of Educational Administration and Secondary Education

AJ Richards
The College of New Jersey
Department of Physics

Melissa Chessler
The College of New Jersey
Assistant Program Director
Robert Noyce Physics Teacher Education Program

Lauren Madden
The College of New Jersey
Department of Elementary and Early Childhood Education

Nathan Magee
The College of New Jersey
Department of Physics

The United States' shortage of well-qualified physics teachers is a crisis at the national scale. With more students than ever enrolling in high school physics courses (White & Tesfaye, 2014), the demand for excellent instructors is skyrocketing. Alarmingly, secondary physics teachers are less likely than teachers of nearly any other subject area to have a degree in the discipline they teach: physics ~40%, chemistry ~40%, biology ~70%, mathematics ~70%, social science and humanities ~75% (T-TEP, 2012). A landscape in which less than half of physics teachers have obtained a degree in this field — especially when coupled with the record number of students taking physics at the secondary level — is extremely worrisome and bodes ill for the US's future scientific literacy. A strong foundation in science in general, and physics in particular, are widely recognized as critical preparation for participation in our knowledge and technology-driven economy (National Academy of Sciences, 2007).

Physics and physics education departments at the postsecondary level have not adequately risen to the challenge of increasing the supply of outstanding new physics teachers. Of the approximately 3,100 new physics teachers each year, only ~1,400 hold degrees in physics (White and Tyler, 2015). This means the shortfall must be filled by teachers with expertise in other subjects being pressed into service in a physics classroom, an unsatisfactory solution for both the reluctant teacher and for the students. The lack of qualified physics teachers is felt especially acutely in high-need schools. In 2002, in response to the dearth of STEM educators, the National Science Foundation established the Robert Noyce Teacher Scholarship Program, which allotted grant money to programs that attract and prepare STEM teachers. In particular, the Noyce program seeks to increase the number of excellent K-12 STEM instructors in high-need schools. A major feature of the Noyce grant program is the provision of scholarships to students pursuing teacher certification in a STEM discipline; scholarship recipients are

committed to teaching for two years in a high-need school district per each year of support. In addition to providing scholarship funding, the Noyce program also supports innovative programming in postsecondary institutions that enhances STEM teacher education and recruitment.

The purpose of the present study is to determine whether any aspect of a Noyce program intervention, in particular a summer program we describe below, affected students' decisions to teach or not teach physics in a high-needs school. Our research was guided by the following questions: (1) In what ways does the program presented here compare to other Noyce programs being conducted at other universities for similar purposes? (2) How do physics majors' ideas about education shift as a result of participating in a summer physics teaching program? Through this research, we hope to gain a deeper understanding of the ways that participants in our program thought about physics teaching prior to participating and how these ideas were shifted or reified by participating. We are further interested in learning which specific aspects of the program were most impactful to participants, and in what ways these experiences are unique to our program or similar to other Noyce program summer internship experiences. By better understanding what aspects of summer internship programs impact participants most deeply, we can identify strengths of our program that are worth sharing and replicating in other Noyce programs.

We begin the chapter with an overview of the challenges to recruitment of STEM teachers, and more specifically, physics teachers. We then explain the methodological framework for the study along with the research context. Here we include an overview of the participants, a description of the program itself and its uniqueness, and the data collected throughout the study. Next, we present our findings, including how the impact of the summer

program presented here compares to that from other Noyce programs. We highlight two representative cases: one participant who came in with interest in teaching and left with a resolved determination of the importance of this path and another participant who was ambivalent at the start of the program, had a positive experience throughout the program, but left still unsure about whether teaching is the right choice for him. These cases and other participant insights highlight some of the themes present in the data including the program's emphasis on educational theory and practical exposure, opportunities for teaching in diverse contexts, and the impact of prior teaching and learning experiences on participants' interest in education. We end with a discussion of the strengths of the program and future areas worth exploring around STEM teacher recruitment.

Current Physics Teacher Recruitment in the United States

Given the dire shortage of physics teachers, it would seem apparent that postsecondary institutions nationwide should be working diligently to address this situation by increasing the number of excellent physics instructors produced each year. However, relatively few college and university physics departments place an emphasis on teacher education, with many failing to recognize this as part of their mission; only approximately 20% of physics departments nationwide have an active physics teacher education program (T-TEP, 2012). Some notable examples of programs that have found success in both traditional and non-traditional physics teacher education and recruitment include the University of Colorado's Learning Assistant program (Otero, Pollock, & Finkelstein, 2010), the University of Texas' UTeach program (Hale, Lopez, Cavallo, & Gonzales, 2017), and institutions that have been recognized by the Physics Teacher Education Coalition's 5+ Club award (PhysTEC, 2018). In addition to the lack of active programs, the fraction of students who wish to pursue a major in physics who also have a strong

interest in a teaching career is often small; graduate study or private industry jobs are paths more commonly envisioned by entering physics majors.

Multiple factors contribute to this mismatch. Particularly harmful is the sentiment that K-12 physics teaching does not bring a high level of academic or professional prestige. Many traditional physics faculty, often implicitly but sometimes explicitly, send the message to physics majors that K-12 teaching is not a career choice worthy of the highest-achieving students (Otero, Pollock, McCray, & Finkelstein, 2006). When asked what a STEM faculty member might say to them were they to express an interest in K-12 teaching, student responses included "don't do it," "you would be wasting your talent," "do it after you retire," and "it is not a full-blown career" (Otero, 2005). This opinion is incredibly damaging to efforts to recruit excellent physics teachers, as teaching is often viewed as a "fallback" career choice, while graduate school or industry employment remain the primary goals for the best students. As a result, many physics students who may have an interest in teaching are conditioned to aim for a more prestigious job.

Contributing to this perceived lack of prestige is the low level of financial compensation awarded to K-12 teachers. Research has shown that salary plays a major role in teacher retention and recruitment (Murnane & Olsen, 1990; Guarino, Santibanez, & Daley, 2006; Rinke & Mawhinney, 2017). This financial pressure can be especially severe for STEM degree holders, as private industry compensation in those fields can often be significantly higher than in education.

While the connected issues of low salary and lack of prestige represent a serious problem, we believe that an important reason that few students pursue a K-12 physics teaching career is that many simply do not really know what a teaching career might entail or have an incomplete understanding of the complexity of a teaching career, and thus pursue more traditional physics degree paths. The intervention we describe in this chapter is designed to address this issue by

allowing physics majors to expose themselves to the experience of teaching physics and feel firsthand the joy and satisfaction that comes from educating others about the subject they love.

Background on Summer Teaching Program

The Noyce Program has been in effect nationally for over 15 years and much of the relevant research has focused on the impact of giving scholarships to participants in exchange for commitment to teaching in high-needs schools after graduating with a teaching certificate. While a significant portion of Noyce support goes toward student scholarships, grant money is also used to increase STEM majors' exposure to teaching experiences in diverse contexts so they can see and feel what teaching is like. As part of the study, we reached out to other Noyce grant recipients to learn about how they designed these programs. Typically internships with informal learning institutions are the model utilized by many Noyce programs. However, the uniqueness of the program presented here is in the deliberate collaboration between scientists and science educators in the development of a theory-to-practice summer program that introduced current research in science education as well as opportunities to plan and implement lessons in K-12 classrooms. This study aims to capture the nuanced and personal experiences of participants, documenting their ideas about teaching before and after the program.

Context for our Intervention

The setting for this study and the cases presented was a small public college in the Northeastern United States that implemented a summer program as part of a Robert Noyce Teacher Scholarship Program grant from the National Science Foundation (Grant No. 1557357). Serving roughly 6,500 students (65% white, 6% Black, 12% Hispanic, 11% Asian), this school identifies as a highly selective public residential college focusing on undergraduate experiences.

The secondary education program graduates approximately 95 students each year, while the physics program graduates 20 students each year.

The primary goal of our Noyce grant project is to roughly double the number of new physics teacher certifications our institution graduates annually in order to: (1) address the shortfall of well-qualified physics teachers, and (2) serve as a model for other primarily undergraduate institutions to emulate as they seek to grow their physics teacher preparation programs. The centerpiece of the grant is the creation of several full tuition scholarships for junior and senior students who are pursuing physics teaching certification and commit to teaching in a high-need school district for two years after graduation. However, there is additional programming supported by the grant, including a dramatic increase in targeted recruiting of prospective physics teacher education students at local high schools (including several high-need districts) and a concerted effort to educate current traditional physics majors about the opportunities a career in teaching high school physics can offer. The focus of this chapter is on a program designed to encourage current physics majors to consider a career in physics education.

Description of the STEP-UP Program

During the Summer of 2017, the project team hosted its first iteration of the Summer Teaching Exploration Program for Undergrad Physics Program (STEP-UP). STEP-UP is a three-week experience designed to expose potential internal transfer students to physics teaching and learning. Key elements of the program included: classroom instruction on physics pedagogy, reform-based science teaching, and working with students in high-needs schools; field visits to local secondary physics classrooms to perform teaching demonstrations; and faculty mentoring from both the School of Science and School of Education at our institution.

The participants met for four hours each day Monday through Friday for a three week period. The meetings were led by one or more faculty instructors. During the first week, the aim was to give the participants a "crash course" in modern, active-learning pedagogy in order to prepare them to develop their own activities later on in the experience. Sample topics during this first week included questioning techniques, backwards design, mental models and conceptual change, inquiry and constructivism, as well as some practical tips such as how to facilitate productive discussions or use demonstrations effectively. As this first week drew to a close, the participants began to develop ideas for their own activities that they would lead during their field visits.

Their activities mostly took the form of interactive physics demonstrations, in which the participant would assume the role of leading a small group of students (5-10) in an exploration of some aspect of a physical phenomenon. Some examples from our sessions included conservation of energy, kinematics, gas laws, and optics. It should be emphasized that in designing their activities, the participants were encouraged to apply what they had recently learned about how students build understanding of physics phenomena from their instruction during the first week of the program; these demonstrations were developed to be fully engaging, ensuring that the students played an active role in their own learning rather than passively sitting and watching a demonstration and/or explanation. In short, we engineered this part of the experience such that the participants would get a taste of what it is like to develop pedagogical materials and activities within an *active-learning* framework, rather than simply telling students about physics.

During the second and third weeks of the program (early June while K-12 schools are still in session), participants visited five local schools to execute the activities they had designed. These schools spanned a diverse set of demographics, most notably in age and ability level (from

4th grade science through 12th grade AP Physics) and socioeconomic status. Logistically, the classroom visits were run as a station or center activity, in which the class would divide into small groups, each of which worked at one station manned by a STEP-UP participant with a collection of demonstrations related to a particular physics topic. After some time had elapsed, the student groups would rotate, going to the next station and working with its STEP-UP participant; this process continued until all groups had rotated through all the stations. During this time, some or all of the faculty mentors circulated around observing the participant-student and student-student interactions. Time-permitting, the participants often performed a particularly flashy demo for the entire class as one large group at the end.

In addition to the school visits, the participants continued to meet daily with the faculty leaders to discuss more advanced educational concepts such as assessment and considerations for teaching in an urban and/or high-need school. The rationale for presenting these topics during the later weeks was that we felt the information discussed during Week 1 (constructivism, questioning, etc.) was more vital to the development of their activities, whereas the ideas discussed during Weeks 2 and 3 were about giving participants a more complete picture of what teaching is like as a profession and the opportunity to begin reflecting upon their classroom experiences.

The culminating project required the participants to design and execute a 45-minute active-engagement lesson about a physics topic of their choosing. This lesson was taught to an audience comprised of the other participants, the faculty mentors, other physics and education faculty, and undergraduate students. This project was meant to give participants a chance to develop and teach a lesson that is appropriate for a class size comparable to that in K-12 schools,

which can be a quite different experience from the small-group interactions they had during their site visits.

Participant Demographics

Potential participants were recruited via flyers and email and responded to the project team to express their interest and to apply. The target audience for recruitment was rising sophomore physics majors not currently enrolled in the secondary education track at our institution. This audience was selected because there is still time to convert those who expressed interest in physics education into the physics teacher preparation track without putting them behind schedule for graduation. Five undergraduates responded and all were accepted into the program. Their demographics can be found in Table 1.

[INSERT TABLE 1]

Comparison to Other Noyce Programs

As part of our research, we sent a call out to other universities that had been awarded a Noyce grant to see the outcomes of programs with similar approaches and goals to ours. We asked for any information about aspects of programs that made them successful or needed to be tweaked, as well as outcomes for the participants (such as whether or not the program had an impact on students' career choice). We reached out to multiple Noyce programs that incorporated some form of summer enrichment in their grant efforts and heard back from 10. Each shared a little about the nature of their summer program and some of their insights as a result of their own data collection efforts. We briefly describe how our program compares to others in the next section; please visit https://physics.tcnj.edu/noyce/ for more detailed information about these various Noyce programs.

One theme common across the programs was the use of internships in informal teaching settings (e.g zoos, museums, summer camps) as spaces for participants to learn more about teaching. Second, there were a lot of challenges to recruiting new students interested in education. Program participants often turned out to be either students who did not have a sincere interest in switching to education but were simply taking advantage of an opportunity to participate in a paid internship, or those already interested in education being eager to gain more opportunities to work with children and youth. Similarly, programs that give stipends or scholarships for summer research also had students using the money to do research and support their résumés but then not participate in the Noyce program. Finally, almost all programs considered their internship program to be successful because it helped with retention of current students interested in education rather than recruitment of new participants. Programs generally attributed their successful retention of students to in-school teaching opportunities (e.g. summer school teaching, classroom visits) and education foundations and methods courses that supported teaching and learning.

Evaluation Methodology

The experience of students in the STEP-UP program was documented utilizing multiple qualitative methods. Student applications to participate in the program asked each applicant to explain why they were interested in participating in the STEP-UP program. These initial responses indicate motivation and interest in a program dedicated to physics education. During the program, multiple science education faculty recorded observations of the participants and at the conclusion of STEP-UP, participants completed an anonymous online questionnaire and a 40-minute focus group discussion, which was recorded digitally and transcribed verbatim. The questionnaire asked each participant to provide demographic information (major, year,

race/ethnicity, gender, and GPA) along with their interest in teaching before and after the program as well as the strengths and shortcomings of the STEP-UP program. The questionnaire and focus group provided an opportunity for participants to reflect on any shifts in thinking about teaching and learning in STEM education and to elaborate on experiences that contributed to these shifts.

Data Analysis

There were two distinct parts to the data analysis for this initial study. The first part of our analysis was comparing the diversity of Noyce programs, specifically those that utilized a similar summer teaching internship model as part of their grant. As part of this analysis, we looked across programs at the ways different universities organized these summer internship experiences, looking for common programming across contexts. The purpose of this meta-analysis of Noyce programs was to first compile a list of grant participants and their associated programs, and then attempt to identify the ways these programs engaged participants in teaching experiences. We found this to be a valuable endeavor as there currently is not a database of Noyce programs, their funding models, program details, and outcomes. Once compiled, this information was used to make comparisons between our STEP-UP program and the outcomes we observed and other Noyce programs in order to identify best practices.

The second part of our data analysis was looking across the STEP-UP participant artifacts to unpack their personal experiences as a result of participating in the program. These data sources included their original application, their final questionnaire, and their final comments during the focus group. A grounded thematic analysis using constant comparison was used to identify trends and themes that emerged across data sources (O'Connor et al., 2008). Each author read through the data independently, then discussed trends that emerged via multiple meetings.

No discrepancies were found in the authors' interpretation of findings. This emergent analysis was guided by our research questions. All authors used the data to identify shifts (or lack thereof) that participants experienced from their original application to the final questionnaire and focus group and what aspects of the program participants cited as most influential to their shifts. In the two cases we present, each participant experienced changes in their thinking as a result of participating in the STEP-UP program and these, along with the specific aspects of the program they found influential, are highlighted.

Two Case Studies

We begin this section by sharing our findings from the meta-analysis of other Noyce programs and how they utilized grant funds to create opportunities for undergraduate students to teach in STEM fields. Next we demonstrate some of our larger findings in the presentation of two participant cases and finally connect these cases to some emergent themes present in the data. By sharing this diversity of data about Noyce programs, and more specifically about the experience of participants in our program, we can begin to make clear connections between the aspects of the program that supported shifts in thinking about physics teaching for participants and how these aspects have been utilized or can be utilized by other Noyce programs.

We selected two participant cases to present, highlighting for each their initial motivation for applying to the STEP-UP program and some of their shifts in thinking about teaching and learning science as a result of participation in the program. The first student, Desmond (all names are pseudonyms) was selected as he represents the student who applied to and participated in the program because he already had a strong interest in teaching. Desmond's journey is emblematic of how a program like STEP-UP can nurture, encourage, and support a student early on in their teacher preparation. In contrast, Arty was selected as a case that

represents the student who is unsure about whether teaching is an appropriate path and how a program like STEP-UP was able to challenge students to think more critically about the role and responsibilities of teachers; however, the student still emerges unconvinced that he is both capable of teaching and would enjoy it as a career. Each student case represents the experiences of the other participants.

Desmond

Desmond came into the STEP-UP program with an enthusiasm for teaching physics. He was already enrolled as a secondary education physics major at the college and his application to the STEP-UP program demonstrated a passion for physics and a strong interest in teaching. Desmond writes in his application:

> I realized I wanted to be a teacher after teaching two short positive psychology workshops to my peers my senior year of high school where I fell in love with being at the front of the classroom. To me, it wasn't just about teaching people for the sake of teaching, it was about the joy of spreading information you think is genuinely interesting and worthwhile for everyone to know and the satisfaction I get when I see people agree with or understand what I'm teaching. (Desmond, STEP-UP Application, April, 2017)

Desmond's response highlights two areas of significance. The first is that, for him, early exposure to teaching had a positive impact on his desire to go into education. The second is that Desmond has ideas about what teachers do. To Desmond, prior to the STEP-UP program, teachers are "at the front of the room" and spread information, satisfied when "people agree with or understand" what is being taught. His preliminary conceptions of who teachers are, what they do, and what brings joy to teachers is shaped by these early educational experiences as a tutor and a learner. Desmond goes on to enthusiastically convey his passion for physics and his

commitment to helping others learn physics. His motivation for applying to the program is to gain early experiences with teaching before beginning his education classes.

Desmond came into the STEP-UP program believing teaching was about passive learning where he is the expert in the classroom "spreading information you think is genuinely interesting" and the satisfaction comes from when you "see people agree with or understand" what is being taught. These notions were challenged throughout the program as Desmond learned about educational theory and the conceptual framework for the Next Generation Science Standards (NGSS) (NRC, 2013). As part of the program, Desmond developed physics lessons for students of all ages (Grades 4-12) about the way light behaves when it comes in contact with different forms of matter. He taught fourth graders on a “Science Matters” day at a public elementary school, as well as worked with middle and high school students in high-needs school districts and introductory physics and AP physics classrooms. During the post-program focus group, Desmond reflects about these teaching experiences in contrast to his own experiences as a learner in high school.

> Growing up, my school was always the opposite [of an interactive classroom]. A lot of my classrooms were classic lecture-based – my one teacher was an old man, and he would sit like this [leans back relaxed in chair] and ramble on about the Hellenistic Age and classic Greek mythology… It was a fantastic class, but I realize now why I – at first I thought I wanted to be a teacher like that, the sage-on-the-stage thing. But now I realize how awesome it would be if I DON’T do that. I don't want to default to that. So it really opened my eyes to different things to try. (Desmond, Focus Group, June 2017)

Desmond initially believed good teaching was "being the sage in the front of the room," but he left the STEP-UP program with a much deeper appreciation for teaching as an active process

where the role of the teacher is about facilitating opportunities for students to struggle with ideas and come to conclusions based on their observations. This shift for Desmond is best evidenced by his experience of finding the perfect material to incorporate into his lesson. He stated, "I stumbled upon the Christmas ornaments, and I'm like, 'There.' I knew exactly. The joy when you find something to teach and then when it works is awesome. It's so rewarding, and that's what I think really makes it worthwhile" (Desmond, Focus Group, June 2017). Desmond shared this story about finding the Christmas ornaments to use with students that would fill a gap in their understanding about the behavior of light. He went on to share how challenging planning lessons is but that it is the kind of challenging that is "awesome," "rewarding," and "worthwhile." He was able to experience the joy of teaching for himself, and that joy resulted from something different than he expected: the joy when learning leads to action.

Desmond's reflections reveal his expectations, where they originated, how his ideas about teaching have shifted, and where these shifts occurred. The two themes evident in Desmond's experience are the excitement one gets from teaching when students are truly engaged and his shift in thinking about the kind of teacher he would like to be. Interestingly, Desmond left the program with a much stronger appreciation for teaching as something rooted in education theory and borne out in classroom practice. After his participation in the program, Desmond expressed interest in conducting education research with faculty, combining his interests in positive psychology and physics teaching. His interest in education research demonstrates his ability to push his own thinking about what teaching looks and feels like for both teachers and students.

Arty

In contrast to Desmond, Arty entered the STEP-UP program with a more negative view of teaching. Arty is a physics major who, in his application to the program, was motivated to participate because he wanted to resolve a tension he experienced between people who have told him he would be a good teacher and his own reservations about teaching. Arty details three main reasons why he does not see himself as someone who would go into teaching.

> From a personal standpoint however I have never given this choice of a career any serious thought for three reasons: 1. My father is a teacher and he seems to very much dislike the people he works with and answers to. I don't want to be in that same position. 2. I don't feel that a teaching career is gratifying enough. While you provide the knowledge for other kids to learn, teaching has quite a low prestige as a general profession and there isn't much else one can do while dedicated to it. As someone who is also interested in being a part of larger scientific projects, this is the main reason I have not given teaching any thought. 3. I fear I don't (or won't) have the patience or confidence for a classroom. (Arty, STEP-UP Application, April, 2017)

It is clear Arty, while claiming to have not given teaching much thought, has thought deeply about why he would not become a teacher. All of Arty's reasons are based on assumptions he has about himself and the teaching profession. He cites his father as an example of a teacher who dislikes his coworkers, he feels teaching would not be "gratifying enough," and he is afraid of not being patient or confident enough for the classroom. However, it is also apparent that Arty's understanding of teaching is limited as he, like Desmond, speaks of teaching as a passive act in which "you provide knowledge for other kids to learn." He is also concerned about the prestige that teaching has within the scientific community and does not feel it is valued and, even worse perhaps, that it is removed from the scientific community to the point where he could no longer

make contributions to "larger scientific projects." Citing this as his main reason for not considering teaching, Arty has internalized the lack of value assigned to teaching by others, particularly those in the hard sciences, and wants to have a career that is valued and contributes to the community. Arty decided to participate in the STEP-UP program because he wanted the opportunity to challenge some of these assumptions. He states in his application:

> This program will allow me hands on experience that will allow me to either confirm or deny some of my previously mentioned uncertainties. I cannot get a better sense of what I excel at without first being in a classroom environment, and the only other way to achieve this is through changing to become a physics-ed major—a very high stakes shift that may not be right for me. (Arty, STEP-UP Application, Spring 2017)

Arty makes his decision to apply to the program because it is a lower-stakes option than completely changing his major to physics education, a move he sees as "very high stakes." The STEP-UP program allowed Arty to see if his ideas about himself and teaching were true. He felt the STEP-UP program would give him the opportunity to figure out this question because it would, "allow me hands on experience that will allow me to either confirm or deny some of my previously mentioned uncertainties."

Arty was committed and engaged throughout the program, and it was clear he had strong teaching skills and the patience that he did not think he had. He prepared lessons on the relationship between potential and kinetic energy and created a can crushing tube that he used for demonstrations and to prompt discussion (Figure 1).

[INSERT FIGURE 1 HERE]

Like Desmond, Arty worked with a diverse range of students and school contexts and demonstrated natural teacher instincts. Observations of him working with elementary school

children noted his ability to modify high level content for younger audiences and his ability to engage learners of all ages in both the activity and in developing conceptual understanding of the can crushing phenomena.

One point of tension for Arty was the difficulty of reconciling his own experiences regarding learning and teaching with the modern pedagogical techniques being described to him. Here we can see how Arty continues to draw from his own experiences as a student even after he has been exposed to theories of active-learning in the program.

> It affirmed my view that the students learn mostly by themselves, which I had figured out just in my own life because I know most of what I learned or a good, substantial portion of what I learned is from TV at home, the Science channel and the Discovery channel, and then the classrooms are places that I can apply my previous knowledge. So I learned the content myself, and then they helped me act on it so that I actually remembered it. And that was why learning was really effective for me. (Arty, Focus Group, June 2017)

Arty speaks here about intrinsic motivation and this notion that we learn what we want to learn and we often do this alone. Drawing on his own experiences as a learner, he cites the various media outlets that helped him discover and appreciate science while identifying school as the place that should tap into that prior knowledge. In some ways, Arty's ideas do align with active learning theories in that the learning takes place in the mind of the student and reflects the deeply personal prior experience and context of the learner. However, it is clear that there remains a disconnect between his somewhat solitary model for his own learning and the social constructivist ideas we discussed during the program.

For Arty, school was meant to be a space for application of knowledge and where deeper learning can take place. Here he cites directly the value of the first week and how he is now able

to understand how providing space to apply knowledge versus direct instruction can be more beneficial to learners.

> But once you get the – when the teachers don't let you apply it in class and just try and teach you directly, I noticed very sharply that my performance goes way down. So that directly corresponds with what we learned in the classroom [during Week 1]. It was just nice to see that there's a reason for it. Again, the first week I learned all about it, and it made a lot of sense. (Arty, Focus Group, June 2017)

Like Desmond, Arty is alluding to the value of seeing theory in practice, both in reflecting on his own experiences as a learner and his experiences through the program. His participation in the STEP-UP program helped solidify a way to articulate and frame some of his initial ideas about learning. However, at the end of the program, Arty was still not convinced that teaching was the right path for him. An idea that emerged during a conversation with Arty immediately following the focus group was the possibility for Arty to teach in an informal learning environment, like a museum or planetarium, where he would have the opportunity to both educate people about physics concepts as well as feel connected to larger science projects.

Interest and Shifts in Teaching

The cases of Desmond and Arty both reveal some of the larger themes that emerged across the participants in the data. Below we highlight how our participants responded to the larger question of how their interest in teaching shifted as a result of the program, something alluded to above by both Desmond and Arty. We also detail the impact that a program with an emphasis on educational theory and practical exposure had on students, and how opportunities to teach in diverse contexts exposed participants to a variety of classroom environments.

Interest in Teaching

Researchers have previously identified the task of increasing students' interest in becoming teachers as vital in teacher recruitment efforts (Kemper & Mangieri, 1985; Villegas & Davis, 2007). Coming into the STEP-UP program, participants retrospectively reported a range of levels of interest in teaching (one low, two medium, and two very high) on their questionnaire. Three participants had considered becoming a physics teacher specifically in the future, and two had not. At the conclusion of the program, all reported either the same level or an increased level of interest in teaching. As one participant shared on the questionnaire, "I would definitely consider it more after being through the program than I did before. Learning about it in the classroom and then teaching in the school was a great way for me to form new ideas" (Arty, Post-program Questionnaire, June 2017).

In the focus group, participants elaborated on reasons why they were interested in teaching. For one participant, teaching is a way to advocate for gender equity in STEM. In her words, "I have always been a great advocate for women in the sciences...I would say that [being a female physics teacher] is something that maybe other females might be interested in. I'd definitely say that my interest has increased" (Caroline, Focus Group, June 2017). For other participants, learning more about modern research-based pedagogy and its relationship to the Next Generation Science Standards sparked an increased interest. For example,

> I think that's the coolest thing for me that really piqued my interest because education lets me blend my interest of physics, teaching people, and positive psychology because I think a lot of the stuff we learned in the first week is stuff that I would like to expand on in the future using that [combination of interests]. (Desmond, Focus Group, June 2017)

Thus, we observed that a program like STEP-UP can enhance students' interest in teaching. And yet, other participants were still uncertain about whether to pursue a teaching career in the future, as emphasized in this questionnaire response:

> I'm still unsure. I found that the lesson presentation was really difficult for me, and I'm not sure how much I could improve on it, either. I'm also not really that sure what I want to pursue as a career in general, though. I want to have some more experience in some other areas of physics before I make my decision. (Jack, Post-program Questionnaire, June 2017)

Shifts in Thinking about Teaching

A strong emphasis in the program was placed on a theory-to-practice model in which participants were first exposed to active learning educational theory (e.g. 5Es learning model for science instruction [Bybee & Landes, 1990]; Understanding by Design [Wiggins & McTighe, 2005]; the framework for the Next Generation Science Standards [National Research Council, 2013], and culturally-relevant pedagogy [Ladson-Billings, 1995]). After a week of modeling NGSS-aligned instruction and engaging in discussions about assumptions about youth in high-needs schools, participants engaged in many practice-based experiences. This general model was valuable to students as they gained new insights into teaching and learning in STEM. Students cited the school visits as the best part of the program and particularly visiting the elementary school as it allowed participants to see how excited and creative children are about learning science. Overall, the program gave a framework for teaching, even if it did not change their likelihood to be a teacher by the inclusion of education theory. Participants also cited a new respect for how difficult and work-intensive teaching is, and how effective physics teaching

requires a deeper process for instructors than simply presenting students with facts or mathematics.

> What I thought was most interesting, and what I really liked was the idea that physics is not just a list of equations to memorize. That's definitely how I was taught physics in high school, but, learning about making physics more conceptual first, really made sense to me. (Jack, Focus Group, June 2017)

Previous studies indicate that exposure to theory with the opportunity to apply theory to a practical context helps to enhance the understanding of theory for preservice teachers (Hascher & Hagenauer, 2016, Allen & Wright, 2014). While not unique to physics teachers, our study supports the notion that an explicit connection between theory and practice, along with opportunity to reflect on the relationship between the two, can support all new teachers in diverse fields.

Interest in Educational Research

Aside from discussion of teaching interest and the strengths and shortcomings of the overall project, participants' responses identified some other key areas of importance. For example, some comments focused on sparking an interest in educational research, or the "science of teaching." One participant noted during the focus group:

> I have a specific interest in doing the research behind the teaching. I know that to really understand that and have a good background, you have to have the in-class experience, the fieldwork, and figure that out before you can really start delving into [educational research]. (Desmond, Focus Group, June 2017)

Another questionnaire response echoed these sentiments as well:

> This problem really has gotten me interested in the science of teaching. I really want to do more research about how different styles of teaching produce different results in students. I hope I can continue to work on projects like that. (Caroline, Focus Group, June 2017)

All participants reflected on the experience of learning about educational theories as valuable and something they would want to continue to explore. For one student in particular, issues of gender equity in science classrooms continued to emerge for her throughout the program. As a female physics education major, she spoke passionately about this as an area for further research. "I'm really interested in getting females involved in science…How can we get more females involved? How can we do this? What methods of teaching can we use to encourage more participation?" (Caroline, Focus Group, June 2017). Furthermore, participants also discussed the value of teaching in high-needs schools as noted in this questionnaire response:

> I would definitely consider teaching in a high needs school because the kids at that school seemed more excited to learn than most of the other kids we saw. I really enjoyed talking to them and their energy was contagious; teaching them gave me energy as well, which is great to feel in the classroom. (Desmond, Focus Group, June 2017)

Finally, the participants unanimously agreed that they found teaching to be harder than they anticipated, particularly because of the level of planning involved. All of these types of observations and questioning in which the participants were engaging speaks to the potential each has for an action research orientation (Cochran-Smith & Lytle, 1999). Our study suggests that these types of orientations can be developed in preservice teachers, and thus, new teachers can feel empowered to investigate the complexities of their unique classroom contexts.

Implications for Program Design

In this section, we highlight what we found to be some essential elements of a program designed to introduce students to teaching physics in a low-stakes environment. These components represent both aspects of the STEP-UP program we found successful as well as feedback from our participants during the focus group after the program. The elements that we would distill out of this experience that might be taken into consideration if planning a similar program include classroom visits with opportunities to teach students in a formal learning environment, a fun and engaging introduction to science education theory and research, an opportunity to explore participants' preconceptions of teaching and how those evolved during the program, and consideration of participants' logistical needs when scheduling the program.

Classroom Visits

Across the board, participants shared that they found the classroom visits and teaching demonstrations to be the most beneficial aspects of the program. As one questionnaire response noted, "Getting an experience in so many diverse classrooms also helped expose us to schools that were likely much different from those we had come from" (Desmond, Post-program Questionnaire, June 2017). Another response stated, "Being able to actually interact with students is a pretty priceless experience. Nothing can really prepare you for the hands on aspect other than actually jumping in and trying to teach" (Caroline, Post-program Questionnaire, June 2017). It is perhaps unsurprising that participants found this to be the most fulfilling aspect of STEP-UP, since most participants applied for the program at least in part to get a taste of engaging with students and actually teaching. In any event, it seems clear to us that giving participants an opportunity to visit classrooms and interact with bonafide physics students is vital to the success of a program of this nature.

Theory to Practice

The participants also shared that the first week of the program, which focused heavily on physics pedagogy, instructional methods, and educational research, was a strength. As one participant shared in the focus group:

> I wouldn't say particularly that this program changed my interest in teaching, but it definitely did narrow down how I look at it in terms of the UbD and the 5 E's and all that that we learned in the beginning. It definitely got [me] to think about how I would go about something in the classroom because up until then...my ideas for teaching were all over the place. (Arty, Focus Group, June 2017).

These comments were mirrored in the questionnaire responses as well. For example,

> I think the lessons given during the first week were really eye opening to show how much work and preparation can go into teaching. These techniques were also very helpful when it was our turn to teach in schools and to prepare our final presentations. (Desmond, Post-program Questionnaire, June 2017)

Again, the participants are making connections between the two spaces of learning the program provided. They consistently mention the value of active learning and modeling during the first week introducing the pedagogical theory of teaching and learning. Pairing their new knowledge with the application into practice allowed participants to see the reflexivity needed in the classroom.

Unpacking Personal Experiences and Assumptions

One common theme that emerged in all of the data is the extent to which personal experiences and assumptions shaped participants' initial understanding of teaching as well as how they were able to shift in their thinking as a result of participating in the program. Personal experiences inform our ideas about teaching and learning, and we recognized the ways our

participants cited their own experiences of schooling in determining why they would or would not consider a career in teaching. Indeed, both Desmond and Arty revealed their prior assumptions regarding what it meant to teach in their applications prior to participating, and they each commented on how STEP-UP altered their understanding of what teaching is all about. Providing opportunities to document initial ways of thinking and where these ideas have been formed and contrasting these at the completion of the program can be beneficial in illuminating the ways assumptions about teaching and learning can shift, and help participants to recognize how an active-engagement pedagogical philosophy can be so different from the passive "presentation" that they expected to be doing.

Lessons Learned

We gave participants the opportunity to provide suggestions for improving the STEP-UP program for future iterations. The suggestions fell into two major categories: extending and improving existing aspects of the program and addressing logistical difficulties.

While participants found the classroom visits to be a real strength of the program, they offered suggestions for improvement. A proposal that received much popular support was to include a day to shadow or observe a practicing physics teacher during the course of a normal workday. It seems that participants enjoyed the feeling of interacting with students but wanted to better know the authentic experience of what a teacher's day is really like. This is understandable; certainly visiting a classroom and working with students for 45 minutes does not give a complete picture of the challenges instructors face daily between teaching multiple grade levels at multiple ability tiers (AP, college-prep, general/core, and the like) while also keeping up with grading, preparation, and other administrative duties. In future offerings of STEP-UP, we plan to schedule a day for participants to observe a teacher in the field to gain a clearer

understanding of this experience. A second suggestion the participants proposed was to extend the classroom visits to include a mandatory trip to an elementary classroom; during this year of the program, the elementary visit was a voluntary addition that was not undertaken by all participants. Even though the vast majority of physics majors who are interested in teaching envision themselves in a high school classroom, we feel it could be enlightening to expose participants to younger grade levels as well.

The second category of shortcomings identified by participants was related to logistical aspects of the program. A couple participants noted that they wished the instructions for the culminating activity (the design and execution of their lesson plan) had been clearer and provided further in advance. In the next iteration of STEP-UP, we will try to ensure the participants better understand what is expected of them for this project. Secondly, since the program runs during the summer and many students do not remain on campus during this time, most participants commuted from home or from other living arrangements. The schedule of the program during the first offering dismissed participants just as rush hour began, making their commutes difficult. In the future, the start and end times will be adjusted to allow for easier travel.

Learning from Multiple Data Sources

The two points of research and analysis described above, a comparison of existing Noyce programs across the US and the exploration of two students' experiences and thematic analysis from participants in our STEP-UP program, are intersecting and informing one another. We first have learned that there is a dearth of formal teaching experiences utilized by existing Noyce programs. We also learned from our participants that it was the opportunity to teach in formal classroom environments that really allowed them to realistically think about teaching as a

potential career. Therefore, we posit that if more formal teaching experiences did exist at other universities, this could provide a more robust and authentic experience to teaching physics in secondary education classrooms. There is still much to explore for future research, including the development of a deeper understanding of the impact of the informal learning experiences that took place at other universities and in what ways those contributed to student interest and desire to teach. However, we feel that the formal classroom aspects of the STEP-UP program were an important factor for its success.

Takeaways for Similar Programs

The dire shortage of well-qualified physics teachers has created a national crisis, and colleges and universities must do more to increase the supply of excellent instructors. In this chapter, we have described a summer program (supported by a Noyce grant from the National Science Foundation) that is designed to encourage physics students who have not declared a formal interest in physics teaching to consider a career in this field. In this program, participants receive basic training in pedagogy and educational theory, work directly to instruct students during field visits to real classrooms, learn more about teaching as a profession, and design and teach a lesson that aligns with modern, research-based pedagogical practices.

Similar to other programs aimed at increasing recruitment of STEM educators through Noyce grants, our findings suggest that the STEP-UP program was effective at retaining and even enhancing the enthusiasm of students already interested in physics education, but was less successful in increasing the number of students changing their majors to physics education. The two case studies we have presented here of Desmond — a student who began the program very interested in a teaching career and became even more so — and Arty — a student who entered the program with doubts about teaching physics and whose conflicting opinions persisted even

afterwards — encapsulate the experiences of the two main types of participant we observed during the inaugural offering of the STEP-UP program. Some common experiences emerged during the program, including an enhanced understanding for the challenges and rewards of teaching with an active-learning philosophy, an appreciation for the interplay between educational theory and practice, and a new interest in science education research. However, as the feedback from participants indicates mixed feelings about their likelihood to choose teaching as a career, it remains difficult for us to conclude that the program has met its primary end goal of converting traditional physics majors into future physics teachers.

Nevertheless, we feel we have distilled a few essential features of the STEP-UP program that helped make it a productive experience. We found that providing participants with a strong foundation in basic pedagogy and educational theory, affording them ample opportunity to experience teaching in actual classroom visits, and ensuring they have a chance to reflect individually and collectively about their attitudes toward teaching — and how those attitudes are evolving — are key aspects of any program of this type. We present these findings to the larger physics and education community because we believe institutions must do more to address the US STEM teacher shortage, and we remain optimistic that programs like STEP-UP that provide opportunities for young people to practice and become exposed to teaching can be an important component of the solution to this important problem.

References

Allen, J. M., & Wright, S. E. (2014). Integrating theory and practice in the pre-service teacher education practicum. Teachers and teaching, 20(2), 136-151.

Bybee, R. W., & Landes, N. M. (1990). Science for Life and Living. *American Biology Teacher*, *52*(2), 92-98.

Cochran-Smith, M., & Lytle, S. L. (1999). The teacher research movement: A decade later. Educational researcher, 28(7), 15-25.

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.

Hale, G. R., Lopez, R. E., Cavallo, A. M., & Gonzales, E. E. (2017). Increasing Physics Teacher Production by Replicating the UTeach Preparation Model and Awarding Noyce Scholarships. Scientia in educatione, 8.

Hascher, T., & Hagenauer, G. (2016). Openness to theory and its importance for pre-service teachers' self-efficacy, emotions, and classroom behaviour in the teaching practicum. International Journal of Educational Research, 77, 15-25.

Kemper, R. E., & Mangieri, J. N. (1985). Student interest in teaching: Implications for recruitment. *The Teacher Educator*, *20*(4), 19-24.

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American educational research journal*, *32*(3), 465-491.

Murnane, R. J., & Olsen, R. J. (1990). The effects of salaries and opportunity costs on length of stay in teaching: Evidence from North Carolina. *Journal of Human Resources*, 106-124.

National Research Council (NRC). (2013). Next Generation Science Standards. Washington, DC: National Academies Press. Retrieved from: http://www.nextgenscience.org/sites/ngss/ les/ APPENdiX%20J_0.pdf.

National Academy of Sciences. (2007). *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: The National Academies Press. Retrieved from: https://www.nap.edu/catalog/11463/rising-above-the-gathering-storm-energizing-and-employing-america-for

O'Connor, M.K., Netting, F.E., & Thomas, M.L. (2008). Grounded Theory: Managing the challenge for those facing institutional review board oversight. *Qualitative Inquiry,* 14, 28-45.

Otero, V. K. (2005). Recruiting talented mathematics and science majors to careers in teaching: A collaborative effort for K–16 educational reform. Public Law, 107, 110-2002.

Otero, V., Pollock, S., McCray, R., & Finkelstein, N. (2006). Who is responsible for preparing science teachers?. Science, 313(5786), 445-446.

Otero, V., Pollock, S., & Finkelstein, N. (2010). A physics department's role in preparing physics teachers: The Colorado learning assistant model. American Journal of Physics, 78(11), 1218-1224.

PhysTEC, http://www.phystec.org/the5plus/, accessed June 2018

Rinke, C. R., & Mawhinney, L. (2017). Insights from teacher leavers: push and pull in career development. *Teaching Education*, *28*(4), 360-376.

T-TEP, 2012. Meltzer, D.E, M. Plisch, and S. Vokos, ed. 2012. Transforming the Preparation of Physics Teachers: A Call to Action. A Report by the Task Force on Teacher Education in Physics (T-TEP). American Physical Society, College Park, MD.

Villegas, A. M., & Davis, D. E. (2007). Approaches to diversifying the teaching force: Attending to issues of recruitment, preparation, and retention. *Teacher Education Quarterly*, *34*(4), 137-147.

White, S., & Tesfaye, C. L. (2014). High School Physics Courses & Enrollments: Results from the 2012–2013 Nationwide Survey of High School Physics Teachers. American Institute of Physics, College Park, MD, 1-3.

White, S., & Tyler, J. (2015). Who's Teaching What in High School Physics?. The Physics Teacher, 53(3), 155-157.

Wiggins, G. P. & McTighe, J. (2005). *Understanding by design*. Ascd.

Author Biographies

Marissa Bellino is an Assistant Professor in the Department of Educational Administration and Secondary Education at The College of New Jersey. She has taught Educational Foundations courses and Science Teaching Methods for Secondary and Elementary preservice teachers. Marissa taught high school in New York City for 11 years and received her doctorate in Urban Education at The Graduate Center, CUNY. Her teaching and research interests include science education, urban environmental education, and youth participatory action research.

AJ Richards is an Assistant Professor in the Physics Department at The College of New Jersey. He received a Masters degree in the field of high-energy experimental physics and a Ph. D. in Physics in the area of Physics Education Research from Rutgers University. AJ's research interests include student reasoning, issues of diversity and equity in physics, and improving teacher preparation. He teaches introductory physics and astronomy as well as secondary science teaching methods courses.

Melissa Chessler is the Assistant Program Director for the Robert Noyce Physics Teacher Education Program at The College of New Jersey. She previously served as the evaluator for several innovative STEM education programs funded by the National Science Foundation and the U.S. Department of Education. Melissa earned her doctorate in Developmental Psychology at UCLA and her M.A. in Educational Psychology, with an emphasis on math, science and technology education, at U.C. Berkeley.

Lauren Madden is an Associate Professor of Elementary Science Education and Coordinator of the Environmental Sustainability Education Minor at The College of New Jersey. She is a former middle school science teacher and teaches courses in science teaching methods and environmental education. She holds a doctorate in Science Education MS in Marine Science and BA in Earth Sciences-Oceanography. Her teaching and research focus on helping teachers to advocate for science and the health of our planet.

Nathan Magee is an Associate Professor of Physics and Director of the Robert Noyce Physics Teacher Education Program at The College of New Jersey. In addition to his work promoting Physics Teacher Education, he conducts experimental research on the physics of high-altitude clouds. Nate earned a Ph.D. in Meteorology from Pennsylvania State University and a B.S. in Physics from Carleton College.