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Building Resilience in Rural STEM Teachers Through a Noyce Professional Learning Community

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Abstract: Addressing the critical STEM teachers' shortage in the rural United States requires not only recruiting new teachers but also improving retention and teacher resiliency. This study explores contextual protective factors through the Early Career Teacher Resilience (ECTR) framework. The major objective of this study was to evaluate the impacts of the NSF Noyce Professional Learning Community (PLC) on rural STEM teacher resilience. Key components of the Noyce PLC included scholarship support, pre-service mentoring, attendance at local and regional educational events, active engagement in the program's annual summer conference, and participation in a closed Facebook group. We developed an ECTR framework-based online instrument with 28 questions and sent it to 311 university alumni, including 44 Noyce alumni. The results suggest that the Noyce PLC has excelled in fostering collaborative learning environments, providing resources that enhance teaching and learning, accommodating new and different ways of thinking, and supporting teachers' professional growth beyond graduation. The findings underscore the importance of integrating theoretical and practical knowledge, supporting ongoing professional learning, and building strong professional relationships. Several aspects of the Noyce PLC could be replicated in other STEM teacher preparation programs to enhance teacher resilience, effectiveness, and career development.

Keywords: professional learning community; teacher resilience; teacher retention; NSF Noyce; teacher preparation; REMAST impacts

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1. Introduction

The alarming trend of teacher shortage issues in the United States is based on declines in teacher education enrollment (Carver-Thomas & Darling-Hammond, 2017; García & Weiss, 2019; Sutcher et al., 2016), attempts to reduce student–teacher ratios (Carver-Thomas & Darling-Hammond, 2017), and ongoing high attrition rates (Bacher-Hicks et al., 2023). In addition, the recent COVID-19 pandemic led some teachers to leave the profession, so the projected shortage gap may be larger (Bacher-Hicks et al., 2023). As the United States and other countries respond to the growing teacher shortage, it is not only important to recruit new teacher candidates to prepare them for the ever-changing

world of education but also to retain teachers. Research on the reasons teachers stay in the profession and what factors, if any, in their teacher preparation affect their resilience (Borman & Dowling, 2008) may lead to an increase in teacher retention rates. Retaining teachers is key to closing the gap (Sutcher et al., 2016). Teacher retention not only affects the shortage but impacts student achievement, teacher collaboration, and district costs (Carver-Thomas & Darling-Hammond, 2019). The current U.S. teacher attrition rate is about 8%, while countries like Singapore and Finland have teacher attrition rates between 3% and 4% (García & Weiss, 2019). Reducing the attrition rate to the level of these two countries could close the gap between supply and demand in the United States (Podolsky et al., 2016). Particularly, the attrition rate of math and science teachers is higher than the overall teacher attrition rate. During the 2022–2023 school year, 45 states reported a shortage of math and science teachers (Irwin et al., 2024). Much of the research in the U.S. has focused on determining why teachers leave (Carver-Thomas & Darling-Hammond, 2019; Ingersoll et al., 2018), but there is a paucity of research on why teachers stay. In this paper, we focus on teacher resilience. Beltman et al. (2011) conducted a review of the empirical research on teacher resilience leading them to classify resilience in terms of risk and protective factors, each of which is further delineated into individual and contextual factors. In their terms, our study is one of the contextual protective factors using a quantitative approach. Because we prepare teachers in a rural area of the country, our interest is in factors that positively prepare future teachers to serve in these settings and support them once they begin teaching.

In the review of rural teacher education by Reagan et al. (2019), about 27% of the articles they reviewed were from Australia and New Zealand. To our knowledge, there has not been a quantitative study on rural teacher resilience in the United States. Since Australia has taken a leading role in rural teacher education research, notably the work by Johnson et al. (2014), we used their Early Career Teacher Resilience (ECTR) framework as the foundation study. Rather than utilizing the traditional definitions of teacher resilience described in the literature (Garmezy & Streitman, 1974; Masten et al., 1990), the ECTR framework (Johnson et al., 2014) corresponds well with the social and cultural contexts we observe in the environments of our graduates. We find that teaching is very social in nature and cultural in the sense that the approach to teaching may differ depending on the district. Johnson et. al. worked with 60 teachers in Australia, of which 47% taught in rural areas, a key factor for the current research being reported here. Johnson et al.'s ECTR framework proposes five categories that contribute to enhancing resiliency in teachers. The ECTR categories are Policies and Practices, Teachers' Work, School Cultures, Relationships, and Teacher Identity. One source of stress for new teachers within Policies and Practices is the national testing environment. These early career teachers indicated that lesson planning, curriculum development, and reflection during their preparation program were helpful to their resilience. Factors within Teacher's Work that were viewed as important were: working with diverse learners, talking with parents, and classroom management. In addition, early career teachers felt that they needed a strong support network to build resilience. Support from a mentor teacher and the school's administrator(s) gave new teachers a sense of belonging, which helped build resilience in School Culture. This ties directly to the Relationships category, where new teachers wanted to have people who asked them how they were doing, etc. A strong Teacher Identity was also seen as a key to resilience. This was most frequently seen in new teachers who were reflective and thought of themselves as learners.

Le Cornu (2013), one of the co-authors of the Johnson et al. (2014) paper, furthered the research on teacher resilience by promoting the concept of relational resilience, focusing on the important role of professional learning communities (PLCs) in teacher resilience.

PLCs build resilience through mutually beneficial interactions between peers and mentors. Forming a PLC with pre-service teachers helped them understand that learning is collaborative and that personal growth is essential in being a resilient teacher (Le Cornu, 2013). Jordan's theory of relational resilience (2023) states, "Resilience is in part the ability to be present in the moment, responding rather than reacting, thus exhibiting emotional flexibility" (p. 74). In Jordan's view, every new teacher is vulnerable, so the ability to recognize this vulnerability and seek support is important to the development of and demonstration of resilience. Another important aspect of relational resilience is that relationships can be mutually beneficial, a contributing factor for why forming a PLC can improve teacher resilience (Jordan, 2023). Papatraianou and Le Cornu (2014) looked at the informal parts of PLCs as being important to teacher resilience. Informal support from colleagues, former peers, and family can help new teachers become resilient. In fact, Gu and Day (2013) posited that teacher resilience is "the capacity to manage the unavoidable uncertainties inherent in the realities of teaching" (p. 39). Papatraianou and Le Cornu (2014) used this definition in their research, acknowledging that peer support is important and that social networks can provide it. Social networks can serve as a venue to share resources and struggles, as well as provide advice. They found that new teachers who had multiple sources of support were able to build a stronger teacher identity and were more confident in their teaching (Papatraianou & Le Cornu, 2014).

The major objective of this study was to evaluate the impact of the Noyce PLC on the resilience of rural STEM teachers. We hypothesized that the notions of resilience embodied in the ECTR framework by Johnson et al. (2014), were best suited for this research. The research questions guiding this study were:

(1) How do ratings of the Teacher Education Department and their Major Department differ between non-Noyce and Noyce participants on selected components of the Early Career Teacher Resilience (ECTR) framework?
(2) Which components of the ECTR framework are most influenced by participation in the Noyce Professional Learning Community (PLC)?
(3) What elements of the Noyce Professional Learning Community can be effectively replicated in other STEM teacher preparation programs?

2. Context, Materials, and Methods

This study was conducted at a rural Midwestern public university, with a medium-sized undergraduate population. South Dakota State University (SDSU) also grants master's and doctoral degrees and is classified as having high research activity. The professional learning community (PLC) we created is built around our National Science Foundation Robert Noyce Teacher Scholarship Program grant, "Rural Enhancement of Mathematics And Science Teachers" (REMAST). The undergraduates seeking secondary certification at our university in both mathematics and science earn content degrees, with teaching certification. The majors that are eligible to receive a Noyce scholarship are biology, chemistry, mathematics, and physics. The mathematics majors take several mathematics education courses taught in the Department of Mathematics & Statistics, so they usually go through the program in cohorts. While the science majors take many of the same science courses, they do not necessarily go through their programs in cohorts. The one course that they take together is a 7–12 science methods course. This course is taught by the science faculty involved in the Noyce project. The mathematics faculty member who serves as the Principal Investigator for the Noyce project teaches several of the mathematics education courses. These science and math faculty interact with all STEM majors and not just the Noyce scholars.

2.1. Noyce Program at SDSU

Our Noyce scholarship program provided USD 10,000 scholarships to selected pre-service math and science teachers at our university. To be considered for the scholarship, undergraduates completed an online application and then underwent a screening and interview process. The scholars were awarded up to two years of funding during their junior and senior years. For each semester of funding received, the scholar must teach in a high-need school district for one year or pay back the scholarship. The first cohort of Noyce scholars was funded for the 2008–2009 academic year.

One of the key components of our Noyce PLC is pre-service mentoring. Pre-service mentoring has taken many forms throughout our scholarship program. These included multiple meetings each semester in various forms: one-to-one student and STEM faculty meetings, small group meetings with STEM faculty, large group book reading, and small group reading. When applicable, Noyce scholars and faculty read books authored by the keynote speaker from our previous annual conference and then discuss them during program meetings.

During the early years of our Noyce scholarship program, scholars were required to attend three events during the semester and then write a brief reflection on these events. The events varied, often depending on whether the student was a junior or senior. Juniors frequently attended student organization meetings, speakers invited to campus, recruitment activities, and science outreach activities, organized by the science faculty that serve as Co-Principal Investigators for the Noyce project. Scholars, particularly student teachers, often attended parent–teacher conferences, school board meetings, team or department meetings, and school activities in which their students participated. Scholars were informed of campus speakers through emails from the Noyce scholarship coordinator, but many of them sought out events for themselves.

In May 2009, supplemental funding from the NSF Noyce program was utilized to offer internships for potential scholars and for funding for an annual workshop, which evolved into the annual REMAST summer conference. The first summer conference was held in June 2011 and has continued annually. All alumni, current scholars, and new scholarship recipients are invited to the annual event. Each conference has a nationally known keynote speaker, often selected based on a selected theme for the conference. This annual conference was held virtually in both 2020 and 2021. In 2020, the conference focused on technologies that teachers found useful in teaching online during the pandemic. While attendance has fluctuated, it is recognized by Noyce scholars as one of the hallmarks of our PLC. “Tonya”, a member of the first cohort who regularly attends the annual conference, said this about the conference:

> But the opportunity to talk to people that are in the same boat, that are struggling with things, that they can share their ideas, I can share my ideas. It gives us a level playing field. Like, I mean, yeah, I’ve got 14 years of experience, but that first-year teacher that just got through their first year may have some really great idea that I’ve never thought of. . . And so, the fact that we’re all together at one, at one level, and there’s no hierarchy.

A closed Facebook group was created in September 2009 to foster engagement with the first alumni cohort who were beginning their first year of teaching. It has become an integral part of our PLC and includes all alumni, current scholars, and faculty with active Facebook accounts. Everyone in the group is allowed to post in the group. Alumni sometimes post job advertisements, questions about handling certain situations, teaching resources they have found, and general questions about pedagogy, classroom management, and communication. The faculty share professional development opportunities, teaching resources, inspirational articles, and articles dealing with the reality of teaching in the

Facebook group. When asked if the REMAST program had met the goal of attracting and retaining high-quality STEM teachers, "Selena", a member of cohort four, said:

> If you look at our Facebook page and our social media. There are so many teachers who are looking for new ideas or commenting on things that Dr. Vestal puts out as resources for us. We're in that age group where we're looking for more information and we're looking for more ideas and things to help us in the classroom.

By May 2020, our Noyce program had recruited and mentored 64 students and produced 61 math and science teachers. The awardees over two subsequent grants included a mix of majors, including twenty-three biology majors, six chemistry majors, thirty-four mathematics majors, and one physics major. About 86% of the students funded under the first grant repaid their scholarship through service. By the conclusion of the second grant, forty-five teachers remained actively engaged in teaching, five were working within the education sector in non-teaching roles, three were pursuing full-time graduate studies, and eleven were no longer teaching, yielding a teaching retention rate of 70%. These Noyce program alumni constituted the treatment group for this study. The primary objective of this study was to quantify and elucidate the factors contributing to these outcomes.

2.2. Data Collection

An online survey instrument with 28 questions (see Supplementary File S1) was partially designed based on specific components from the ECTR framework, which were selected based on alignment with our Noyce program, as shown in Figure 1. A few questions came directly from the National Center for Education Statistics Schools and Staffing Survey. Several questions were demographic in nature, some were related to their commitment to teaching, and we also asked about plans to obtain a master's degree. This survey was distributed to all university alumni of our secondary certification programs, including the Noyce program alumni who graduated during our first Noyce grant. In addition to the survey, we have selected quotes from interviews conducted as part of the program evaluation. These interviews were conducted by Dr. Robert Burke in his role as the external evaluator for the project.

2.3. Participants

The online survey was sent to all 311 (44 Noyce and 267 non-Noyce) university alumni with secondary education certification who graduated between December 2008 and May 2014. These non-Noyce alumni names were gathered from our university's Data Center and included graduates with secondary certification in the following areas: Agricultural Education, Art, Biology, Chemistry, English, Family & Consumer Sciences, Geography, German, History, Mathematics, Music, Physical Education, Spanish, and Speech Communication. Attempts to find current email addresses for all alumni were unsuccessful. If we could not find a current email address, the survey was sent to their university student email address. We later found that these accounts frequently go inactive and that many of the alumni likely never received the survey. Alumni were offered an incentive to complete the survey, a chance to win two football tickets to the homecoming football game. Two pairs of tickets were available, and the winners were drawn at random from those that fully completed the survey.

Policies & Practices	Teachers' Work	School Culture	Relationships	Teacher Identity
Policies and practices refer to the officially mandated statements, guidelines, values, and prescriptions that both enable and constrain ECT well-being. ECT resilience and well-being are enhanced when policies and practices show a strong commitment to social justice, teacher agency and voice, community engagement, and respect for local knowledge and practice.	Teachers' work refers to the complex array of practices, knowledge, relationships and ethical considerations that comprise the role of the teacher. ECT resilience is promoted when the focus is on understanding the complex, intense and unpredictable nature of teachers' work rather than on individual deficits and blame.	School culture refers to the values, beliefs, norms, assumptions, behaviors and relationships that characterize the daily rituals of school life. ECT resilience flourishes in schools that promote collaborative relationships, professional learning communities, educative forms of leadership and democratic decision-making.	Relationships refers to the social and professional networks, human connections and belongingness experienced by ECTs. Schools that value relationships focus on the complex emotional needs of ECTs and encourage social exchanges that foster respect, trust, care and integrity. ECT resilience benefits significantly when these values are evident in policies and practice.	Teacher identity refers to the development of one's awareness and understanding of self as a teacher. Teacher resilience is enhanced when ECTs engage in processes of self-reflection and self-understanding that sustain their personal identity, while at the same time developing a robust teacher identity.
To enhance ECT resilience, it is important to:				
• Provide relevant, rigorous and responsive pre-service preparation for the profession **Provide diverse, rigorous and carefully planned pre-service professional experiences** **Ensure coherence between on-campus courses and the dynamic demands of the profession** • Create innovative partnerships and initiatives that assist smooth transitions to the workforce **Support professional development suitable to the school context**	• Acknowledge the complex, intense and unpredictable nature of teachers' work **Acknowledge that teachers' work is demanding and tiring** • Develop teachers' curriculum and pedagogical knowledge and strategies **Provide opportunities for collaborative planning, teaching, assessment, and reporting** **Promote innovative and engaging curriculum practices** • Provide support to create engaging learning environments **Create collaborative and democratic learning environments**	• Develop a professional learning community **Promote opportunities for risk-taking and innovation** **Provide environments and resources that optimize teaching and learning**	• Promote a sense of belonging, acceptance and wellbeing **Foster relationships based on mutual trust, care and integrity** **Encourage involvement in professional and community networks** • Place student-teacher relationships at the heart of the teaching-learning process **Develop learning communities where everyone encourages each other's learning** **Celebrate student innovation and success in and beyond the classroom** • Foster professional growth **Value the personal strengths and resources of teacher candidates** • Promote collective ownership and responsibility for professional relationships **Share responsibility for maintaining positive relationships**	• Understand the interplay between personal and professional identities **Recognize that personal and professional identities are interconnected** **Recognize that teachers' identities are produced in particular social and cultural contexts** • Engage in self-reflection **Accommodate new and different ways of thinking** **Challenge and develop beliefs, assumptions, values and practices** • Foster a sense of agency, efficacy and self-worth **Commit to the ethical and moral purposes of teaching** **Seek help and support**

Figure 1. Selected Early Career Teacher Resilience (ECTR) framework conditions (Johnson et al., 2014) as applied to the REMAST program. Our survey instrument content was based on colored bolded items in the bottom row.

2.4. Survey Instrument

The survey instrument provided as Supplementary File S1 was used in this study. In addition to the ECTR framework statements, participants were asked demographic questions to provide for further analysis of control and treatment groups. The institutional review board found this study to be classified as exempt (IRB-1509015-EXM). Survey Question 1 explained the study and served as the participant's consent to participate. The next four questions of the survey were demographic questions regarding what grade level taught, major(s) and minor(s), certification areas, and the academic year that they began teaching. We took a few questions from the U.S. Department of Education National Center for Education Statistics Schools and Staffing Survey (NCES survey) that was administered during the 2007–2008 school year. One of the reasons that we did this was because they were following several of those teachers in a longitudinal study using the Teacher Follow-Up Survey. These questions that were identical or like the NCES survey questions were Questions 6, 7, 8, 9, 19, 22, and 25. More demographic information was requested in Questions 10 through 12. Question 13 asked if they had a faculty member with whom they interacted regularly while in the Teacher Education program., while Question 14 asked if they have engaged with their faculty mentor since they graduated and how often. Questions 15, 16, and 18 were 5-point Likert-type scale questions, based on statements (in Table 1) from the ECTR framework. The respondents were asked the same questions at least twice: the first time rating the South Dakota State University (SDSU) Teacher Education Program, the second time to rate their SDSU Major Department, and if they were Noyce PLC alumni, the third time to rate the Noyce program. The Likert-type scale anchors (from left to right) were: Strongly Disagree (1), Disagree (2), Neither Disagree or Agree (3), Agree (4), Strongly Agree (5), and NA (6). Question 20 asked how long they had been teaching, while Question 21 asked if they had received a scholarship/grant that required a mandatory number of years of teaching service. Question 23 asked those alumni who had already left teaching if they would return to teaching. Question 24 asked for circumstances as to why they left teaching. Question 26 was their contact information for the random drawing. Respondents were required to complete the contact information question to be eligible for the drawing. The last two questions were demographic information.

The ECTR framework divided the various items of importance into five categories: Policies and Practices, Teachers' Work, School Culture, Relationships, and Teacher Identity. When selecting items from each category for the Likert-scale questions, the Relationships and Teacher Identity categories were over-sampled due to their focus as a key component of our PLC. Some of the questions are directly related to the Noyce PLC. For example, "encourage involvement in professional and community networks" and "develop learning communities where everyone encourages each other's learning". A couple of others relate to supports provided by the Noyce PLC, such as "recognize that teachers' identities are produced in particular social and cultural contexts" and "seek help and support".

2.5. Validity

The validity of this study was established through a rigorous alignment of the research design, data collection, and analysis methods with the Early Career Teacher Resilience (ECTR) framework. This theoretical foundation informed the construction of the survey instrument, ensuring that the questions addressed the five key categories of resilience: Policies and Practices, Teachers' Work, School Culture, Relationships, and Teacher Identity. To enhance content validity, the survey items were adapted from established instruments, including components from the National Center for Education Statistics Schools and Staffing Survey, and reviewed to ensure relevance to the context of rural STEM teaching.

Internal consistency of the constructs was confirmed using Cronbach's alpha, with values ranging from 0.925 to 0.960, indicating excellent reliability of the survey instrument. This demonstrates that the items within each construct consistently measured the intended aspects of teacher resilience. Furthermore, the use of non-parametric statistical tests, such as the Mann–Whitney U test and the Kruskal–Wallis test, ensured robust analysis despite the limited sample size, addressing potential concerns about statistical validity.

While the sample size was modest, the study mitigated threats to validity by focusing on a clearly defined population—alumni of the Noyce PLC—and employing a theoretically grounded framework. Including both Noyce and non-Noyce alumni allowed for comparative analysis, and the balanced representation of the ECTR framework categories ensured comprehensive coverage of teacher resilience constructs. These measures collectively support the validity of the findings and underscore the study's contributions to understanding resilience in rural STEM educators. Future iterations of the survey and longitudinal designs are recommended to further validate and expand upon these findings.

3. Results and Discussion

We received 97 complete responses, 28 were alumni from the Noyce program, resulting in an overall response rate of 31% with a response rate of 64% from our Noyce PLC. This response rate was lower than the average (Wu et al., 2022), but it was quite long so some respondents started the survey but then dropped out. The respondents were 69% female and 31% male. The average number of years of teaching was about 4 years across all respondents. Of the scholarship alumni, 100% of them had taught some after graduation, while 9.5% of the alumni (not from the scholarship program) never taught after graduation. This is not surprising because the scholarship recipients are required to teach to "pay back" the program with service.

Table 1. A comparison of self-reported salary range of first teaching job of REMAST alumni (Noyce) and other university alumni (non-Noyce) of science and math teaching certification program.

Salary Range for First Year	Less than USD 25,000	USD 25,001 to USD 30,000	USD 30,001 to USD 35,000	USD 35,001 to USD 40,000	USD 40,001 to USD 45,000
Noyce	3.57%	42.86%	39.29%	10.71%	3.57%
Non-Noyce	5.00%	13.33%	65.00%	16.67%	0.00%

3.1. ECTR Framework Data Analysis

Question 6 of the survey is on the salary of their first teaching position and was taken directly from the NCES survey (see Table 1). A chi-square goodness of fit test was used on the salary data to compare the salaries of the Noyce and non-Noyce respondents. It was hypothesized that each range would have an equal number of respondents. Significant deviation from the hypothesized values was found (χ^2 (2) = 10.077, p = 0.0065). Therefore, the Noyce participants had lower starting salaries even though they were teaching in the high-need fields of science and mathematics. We suspect that this can be attributed to the fact that the Noyce alumni are required to teach in "high-need districts", which likely have less funding. Research on teacher salary variations between graduates who received federal scholarships and those who did not is somewhat limited. Although annual funding reports show how the Noyce scholarship program positively impacted individual scholars, long-term tracking of the impact, including their salary range and resiliency, is yet to be investigated. The lower salary categories are included because the respondents are first-year teachers between 2009 and 2015. The respondents in the less than USD 25,000 category could be teaching part-time or at a private school.

While we expected differences in our Noyce and non-Noyce alumni, it is important to address areas where the groups were similar. Looking at the results of Question 10 in Table 2, where they were asked to classify the type of community in which they teach, we conducted a chi-square goodness of fit test. The hypothesis was that each range would have an equal percentage of respondents. No significant deviation from the hypothesized values was found (χ^2 (2) = 0.086, p = 0.9579). We can say that the groups are more similar regarding the teaching community than they are different. In both groups, the largest communities represented are rural communities. This is not surprising because of our location in the U.S., but it also illustrates that most of our university alumni are teaching in communities that many would consider very rural.

Table 2. Comparing the communities served by Noyce and non-Noyce graduates.

Population of Community	Urban (More than 50,000)	Suburban (2500 to 50,000)	Rural (>2500 People)	Other
Noyce %	10.71%	39.29%	46.43%	3.57%
Non-Noyce %	10.00%	43.33%	45.00%	1.67%

At our university, pre-service teachers earn content degrees from the content departments and take courses for secondary teacher certification from the Teacher Education program. Because of this structure, the following results are not surprising. When comparing the non-Noyce and Noyce ratings of the Teacher Education Department and their Major Department on the 23 ECTR framework components, there were no low p-values. Since the Likert data were not normally distributed, the comparison was performed using the Mann–Whitney U test. It is not surprising that there were no low p-values since all alumni were in the same Teacher Education program, and all alumni in each content area (biology, chemistry, English, mathematics, etc.) rated their own Major Department.

While there was no difference between the two groups' ratings of the Teacher Education and Major departments, when we examined the Noyce alumni's ratings of the three programs: Teacher Education, Major Department, and Noyce, we did find some statistically significant differences (α = 0.05). To analyze these data, we used a Kruskal–Wallis test to determine if there was a difference between the programs. Then, for the post hoc analysis, we used a pairwise Wilcoxon rank sum test with a Bonferroni p-value adjustment. The Bonferroni adjustment was used as it is more conservative, and we did not want to falsely say that there is a difference in ratings when there is not (Haynes, 2013). When performing the pairwise comparisons, the differences were between the Noyce and Teacher Education programs. Again, it is unsurprising that differences were not seen between Noyce and the Major Department as the content faculty in science and math are an integral part of the Noyce project team. The results are below in Table 3, with the ECTR components with low p-values in bold.

The Noyce alumni rated the Noyce program higher than the Teacher Education program for eleven of the twenty-three questions at a significance level of $\alpha < 0.05$. Two of these fell under the Policies and Practices category, two of them were under Teachers' Work, two fell under School Culture, two involved Relationships, and three of them involved Teacher Identity. The fact that the statistically significant results were balanced throughout the five categories in the ECTR framework is evidence that this framework fits our project well.

Table 3. Noyce alumni averages for each program, Kruskal–Wallis *p*-value, and Wilcoxon *p*-value.

ECTR Framework Component	Teacher Ed Average	Major Dept Average	Noyce Average	Kruskal–Wallis *p*-Value	Wilcoxon Rank Sum *p*-Value for Noyce v Teacher Ed
Provided diverse pre-service professional experiences.	3.5517	3.8000	3.9630	0.0902	
Provided carefully planned pre-service professional experiences.	3.7586	3.5600	3.9630	0.1885	
Ensured coherence between on-campus courses and the dynamic demands of the profession.	3.2414	3.8400	4.1071	0.0016	0.0015
Supported professional development suitable to the school context.	3.6552	3.8333	4.3214	0.0029	0.0042
Acknowledged that teachers' work is demanding and tiring.	3.8966	4.0000	4.3214	0.2181	
Provided opportunities for collaborative planning, teaching, assessment, and reporting.	4.0000	3.6923	4.2143	0.0773	
Promoted innovative and engaging curriculum practices.	3.6207	3.7407	4.1429	0.0338	0.024
Created collaborative and democratic learning environments.	3.7586	3.8148	4.2857	0.0218	0.0085
Promoted opportunities for risk taking and innovation.	3.4138	3.8148	4.0714	0.0226	0.018
Provide environments and resources that optimize teaching and learning.	3.5517	4.1154	4.2500	0.0022	0.0044
Fostered relationships based on mutual trust, respect, care, and integrity.	4.1379	3.9630	4.2857	0.3175	
Encouraged involvement in professional and community networks.	4.0345	4.0370	4.3704	0.0804	
Developed learning communities where everyone encourages each other's learning.	3.8276	4.0741	4.2857	0.0621	
Celebrated student innovation and success in and beyond the classroom.	3.9286	3.8462	4.2500	0.0896	
Valued the personal strengths and resources of teacher candidates.	4.0000	3.7500	4.4286	0.0080	0.023
Shared responsibility for maintaining positive relationships.	3.8966	3.9259	4.3571	0.0107	0.016
Recognize that your professional identity as a teacher is connected to your personal beliefs and knowledge.	3.8276	3.8636	4.1071	0.4341	
Recognized that teachers' identities are produced in particular social and cultural contexts.	3.8276	3.6522	4.1071	0.1171	
Accommodated new and different ways of thinking.	3.5172	3.8148	4.2143	0.0092	0.0067
Challenged and developed beliefs, assumptions, values, and practices.	3.6071	3.8148	4.1786	0.0260	0.017
Encouraged you to commit to the ethical and moral purposes of teaching.	4.3103	3.9583	4.2500	0.2212	
Encouraged you to seek help and support.	4.0345	4.2593	4.3704	0.3694	
Offered assistance with your teaching and learning beyond your time at SDSU.	3.6207	4.1667	4.4643	0.0025	0.0022

3.2. Policies and Practices

Within the Policies and Practices category, as shown in Figure 2 we see a difference between the Noyce program and the Teacher Education program in two components: "ensured coherence between on-campus courses and the dynamic demands of the profession" and "supported professional development suitable to the school context". One possible explanation for the observed difference in professional development may be explained by the Noyce program support of scholars' travel to state and regional math and science education conferences. In addition, the annual summer conference that began in 2011 brings together Noyce alumni and scholars to learn from national speakers and each other.

Our Noyce program led to the development of the student chapter of the National Science Teachers Association (NSTA) at our university. One of the requirements of the scholars is that they belong to a student organization so most choose to belong to the student chapter of NSTA, the student chapter of the National Council of Teachers of Mathematics (NCTM), or the student National Education Association (NEA).

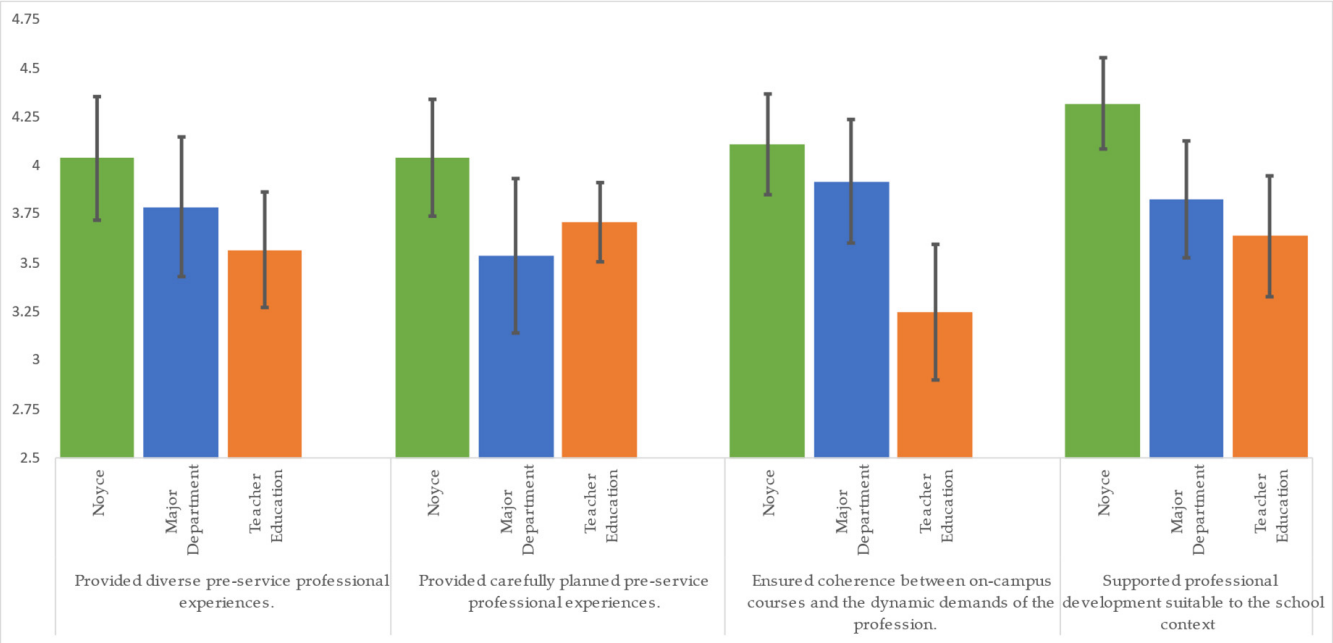

Figure 2. Noyce alumni ratings of each "program" for ECTR components in Policies and Practices. Green bars represent the ratings of the Noyce community itself, blue bars represent their rating of their Major Department, and orange bars represent their rating of the university's Teacher Education program. The ratings were converted from a Likert scale to a numerical scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neither Disagree nor Agree, 4 = Agree, and 5 = Strongly Agree. The scale on the *y*-axis starts at 2.5 and the black bar indicates the 95% confidence interval of the mean.

Our findings in the Policies and Practices category, especially the notable difference in how well the program aligns coursework with professional needs, align well with the ECTR framework's focus on blending theory with practice (Johnson et al., 2014; Smith & Ingersoll, 2004). The Noyce program's success in linking academic learning to real-world teaching challenges fits with the ECTR's "Curriculum" component, which calls for curricula that address real classroom needs (Bali & Cohen, 1999). Moreover, the emphasis on professional development tailored to the school context reflects the ECTR's "Support" component, highlighting the relevant and ongoing professional learning (Desimone, 2009). The Noyce program's success in fostering collaboration through activities such as the annual summer conference, student club activities, and group projects can serve as a model for other STEM teacher preparation programs. One aspect of the Noyce program that could be effectively replicated in other STEM teacher preparation programs is the structure of professional development opportunities. The combination of supporting travel to conferences and the organization of an annual summer conference that brings together alumni and current scholars creates a robust learning community (Wenger, 1999). This community supports continuous professional growth and can be a model for other programs seeking to enhance the coherence between academic preparation and professional practice (Grossman et al., 2009). Regarding our annual summer conference, Selena said:

> So I think by having really engaging speakers that helps. The other thing that I love is each year at the conference not only is it just professionals that we've never seen before but it's our peers that are coming up and presenting about what they do or what they know or what they've seen in the classroom. And because you have that connection with them, we have built that community. I know them, I recognize their face, . . . I trust them a little more too.

3.3. Teachers' Work

There was only one component within *Teachers' Work* in which the alumni rated the Noyce program significantly higher than Teacher Education (Figure 3), "created collaborative and democratic learning environments". However, another one where the rating is somewhat higher is "promoted innovative and engaging curriculum practices". We encourage collaboration and innovation in our Noyce program. This is particularly noticeable at the annual summer conference. We have carried out several group activities during the conference including a campus scavenger hunt and building a paper roller coaster for a marble. The teams for these activities are created by pairing both math and science teachers together with pre-service teachers. This allows our veteran teachers to interact closely with the scholars and new teachers.

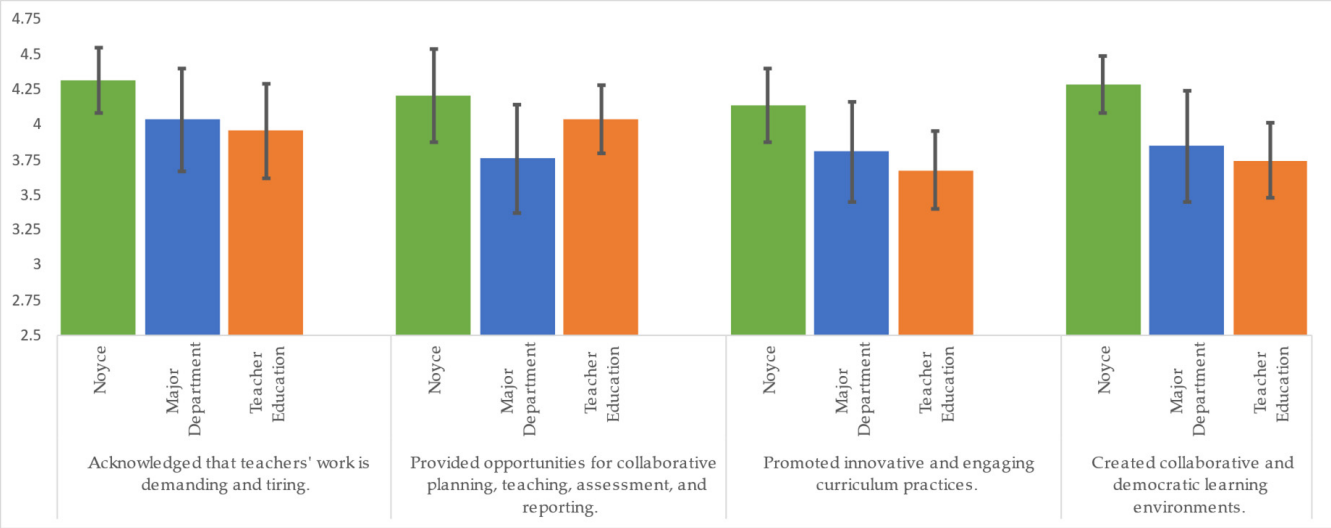

Figure 3. Noyce alumni ratings of each "program" for ECTR components in Teachers' Work. Color coding of the bar charts and conversion of the Likert scale to a numerical scale are described in Figure 2.

Looking at Figure 3, it is easy to see that the largest difference between Noyce and Teacher Education is in the component "created collaborative and democratic learning environments", which had a p-value of 0.0085. While the bar chart does not show much difference in "promoted innovative and engaging curriculum practices", we did have a p-value of 0.024 when performing the pairwise comparison.

The ECTR framework places a strong emphasis on collaborative learning environments and the development of innovative practices, which are reflected in the findings under the Teachers' Work category (Johnson et al., 2014; Johnson & Kardos, 2002). The significant difference in the component "created collaborative and democratic learning environments" corresponds directly with the ECTR's "Pedagogy" and "Community" elements, where collaboration and democratic practices are seen as essential to effective teaching (Darling-Hammond, 2015). The higher ratings for promoting innovative curriculum practices further underscore the importance of fostering an environment where

creativity and collaboration are encouraged, as advocated by the ECTR framework (Sawyer, 2004). The Noyce program's success in fostering collaboration through activities such as the annual summer conference and group projects can serve as a model for other STEM teacher preparation programs (Garet et al., 2001). Replicating these practices can help other programs develop a similar sense of community and innovation among their pre-service teachers (Little, 2002). Specifically, creating opportunities for pre-service and in-service teachers to work together on collaborative projects can enhance both teaching practice and professional development, aligning with the ECTR's focus on a collaborative teaching culture (Hord, 1997).

3.4. School Culture

Within the *School Culture* category, only two items were utilized, because our program has no control over this category. While both had low *p*-values as visualized in Figure 4, the component where the Noyce rating was much higher than Teacher Education was "provide environments and resources that optimize teaching and learning", which had a *p*-value of 0.0044. In addition, "promoted opportunities for risk-taking and innovation" had a *p*-value of 0.018. While the Noyce program has no control over school culture, these components may indicate that scholars were confident in their teaching and are willing to try new things.

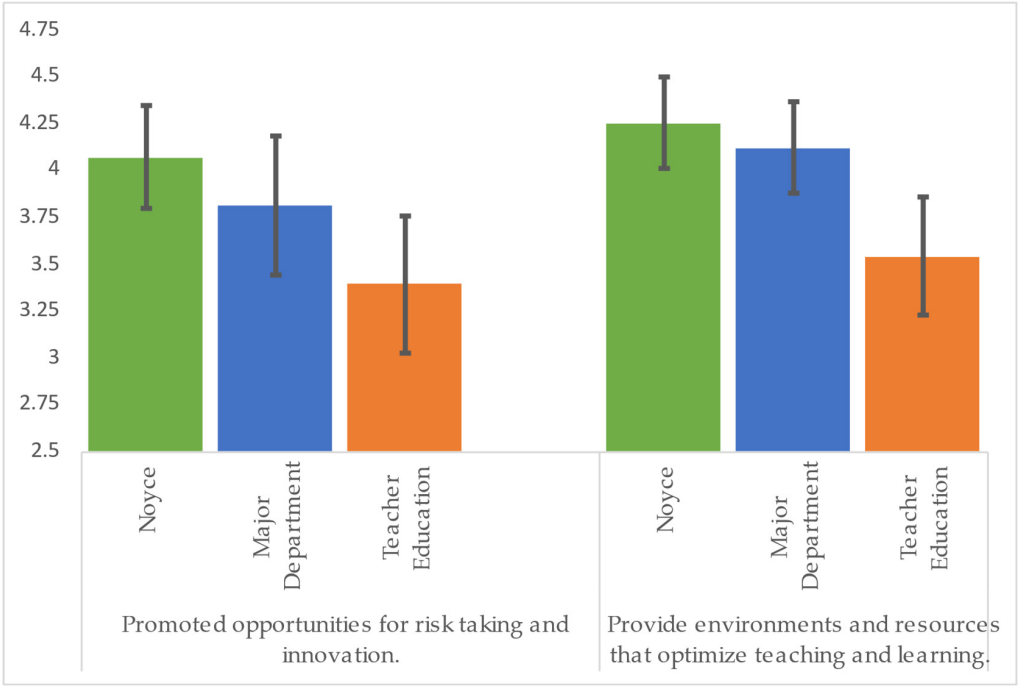

Figure 4. Noyce alumni ratings of each "program" for ECTR components in School Culture. Color coding of the bar charts and conversion of the Likert scale to a numerical scale are described in Figure 2.

In the past few years at the conference, each participant received a copy of the keynote author's book. Then we use that book as part of our group mentoring meetings for the scholars and faculty the following year. Our Noyce program emphasizes that STEM teachers need to constantly learn new things and reflect on their teaching. The use of book studies and the summer conference to reinforce professional learning reflects the framework's emphasis on creating environments that support continuous professional growth and learning (Guskey, 2002). Other STEM teacher preparation programs could replicate the Noyce program's approach to creating a supportive teaching environment by implementing

similar book studies and professional learning communities (Le Cornu, 2013). Integrating these elements into the curriculum of other programs could enhance their effectiveness in preparing teachers for the dynamic demands of the classroom (Guskey, 2002).

3.5. Relationships

Before administering the survey, we hypothesized that we would see higher ratings of the Noyce program in the Relationships category. As shown in Figure 5, all three departments were rated very highly. The ECTR framework underscores the importance of building strong relationships within the teaching community, which is reflected in our data as well. The higher rating for the component "shared responsibility for maintaining positive relationships", with a p-value of 0.016, aligns with the ECTR's "Community" and "Support" elements, which emphasize the role of positive, collaborative relationships in effective teaching (Darling-Hammond, 2015). Another component with a statistically significant difference is "valued the personal strengths and resources of teacher candidates", with a p-value of 0.023. This component illustrates the respect that the faculty has for the Noyce scholars, which is evident throughout the program. We value their input and frequently ask for their feedback on the program and how to improve it. When asked what value the annual conference has been, "Lola" from cohort 5 said, "Networking. I've gotten a lot of great ideas from my peers in this program both math and non-math and that's especially important because I don't have a department at my school. I am the department".

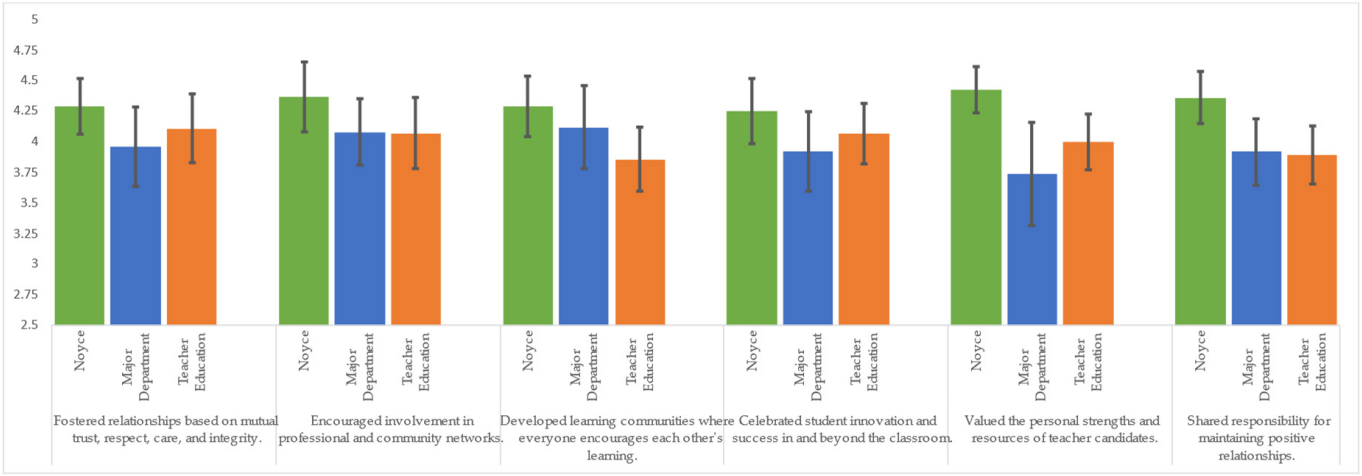

Figure 5. Noyce alumni ratings of each "program" for ECTR components in Relationships. Color coding of the bar charts and conversion of the Likert scale to a numerical scale are described in Figure 2.

The Noyce program's ability to foster strong relationships among scholars, faculty, and alumni highlights the importance of community in teacher preparation, as outlined in the ECTR framework. To replicate the success of the Noyce program in building strong relationships, other STEM teacher preparation programs could focus on creating similar opportunities for faculty and students to interact in various contexts (Little, 2002). This could include integrating faculty into project teams, organizing collaborative events, and establishing a formal and informal mentoring network.

3.6. Teacher Identity

Three items from the Teacher Identity category of the survey showed a much higher rating of the Noyce program over Teacher Education. These were "accommodated new and different ways of thinking", "challenged and developed beliefs, assumptions, and practices", and "offered assistance with your teaching and learning beyond your time at

the university". These components had p-values of 0.0067, 0.017, and 0.0022, respectively. These differences are illustrated in Figure 6, where the 95% confidence intervals do not overlap.

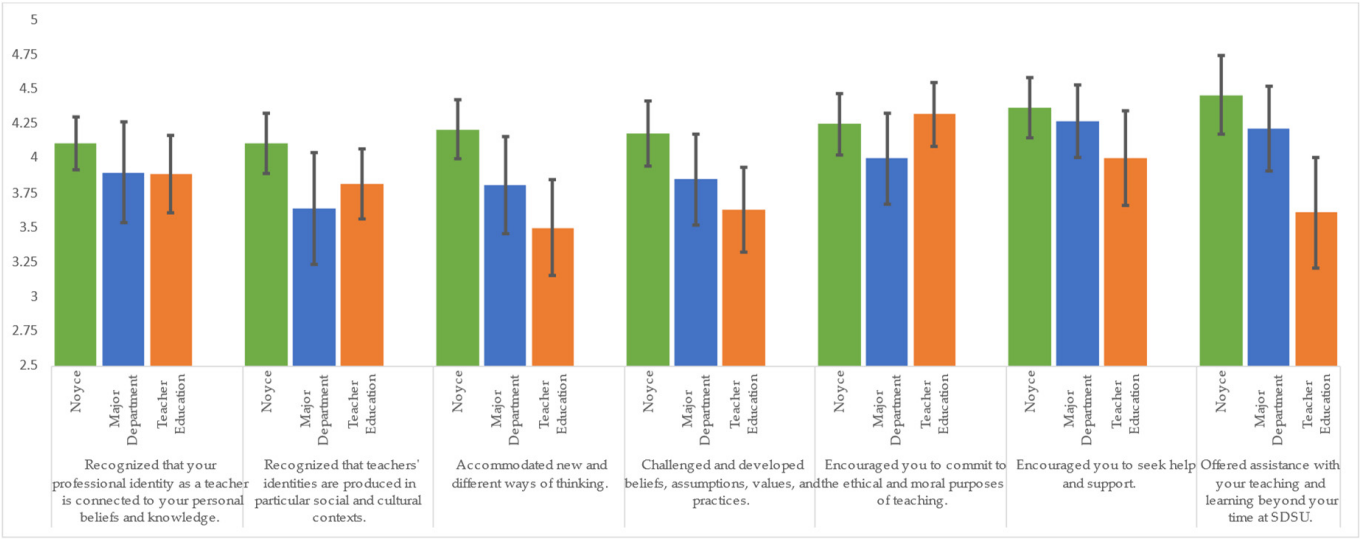

Figure 6. Noyce alumni ratings of each "program" for ECTR components in Teacher Identity. Color coding of the bar charts and conversion of the Likert scale to a numerical scale are described in Figure 2.

The closed Facebook group has helped build and strengthen our Noyce community. The activity within the Facebook group has grown with more alumni posting recently than in the past. The component within the Teacher Identity category with the smallest p-value is "offered assistance with your teaching and learning beyond your time at SDSU". This aligns well with the ECTR framework's emphasis on "Support" and "Reflection". The Noyce program's commitment to supporting alumni beyond graduation reflects the ECTR's view that teacher identity is continuously shaped through ongoing professional development and reflection (Kennedy, 2016). This sustained support helps teachers integrate new ways of thinking and adapt to evolving educational challenges, a key aspect of the ECTR framework. Other STEM teacher preparation programs could replicate the Noyce program's approach by establishing long-term support networks for their alumni, such as closed social media groups and regular alumni events like the Noyce Conference each summer. These networks can provide ongoing professional development and a platform for reflection, which are essential for the continued growth of teacher identity (Vescio et al., 2008). By maintaining strong connections with graduates, other programs can ensure that their teachers continue to receive the support they need to thrive in their careers, aligning with the ECTR framework's focus on lifelong learning and professional development (Cordingley et al., 2019).

Through our analysis, we have identified 11 components in which the Noyce alumni rated the Noyce program higher than the Teacher Education program with statistical significance. These are summarized in Table 3. Looking at these components, we have come up with the following themes: a collaborative learning environment, shared resources to improve teaching and learning, mutual responsibility for continued positive relationships, and assistance beyond graduation. Comparing these themes with the teacher resilience literature, we see several commonalities. Relationships play a major role in several areas and align with Jordan's (2023) idea of relational resilience, which is based on relationships within a professional learning community. Our Noyce scholars clearly feel we have built a community and that they can rely on others in the community for support. During our

mentoring meetings with the pre-service teachers and the annual summer conference, Noyce alumni and scholars share similar experiences. This gives them mutual empathy and mutual empowerment, which helps them grow in courage and confidence, so they are resilient teachers. "Debbie" from cohort two noted, "So, creating that community helped confirm what we were doing, and even with the students, because we were a small group of us going through the program together. We kind of had each other, which was really awesome".

Utilizing Gu and Day's (2013) idea of teacher resilience as the ability to handle unforeseen circumstances, the Noyce program makes the realities and demands of teaching very clear when our alumni share experiences at the annual conference. When responding to a question about her preservice mentor, Selena stated, "And so talking with him early on allowed us an opportunity to talk about issues in teaching and how we would combat those and how we can work around them and work through them and become successful educators". When our scholars graduate, they are very aware of how hard their first year of teaching will be, but they also know that they can seek support from the faculty, their peers, and other alumni through email, text, or the Facebook group. While our Facebook group was created in 2009, we did not see many alumni posts until the last few years, where alumni are now more comfortable asking questions, sharing resources, and encouraging one another. In particular, the Noyce program director posts frequently, which helps maintain that connection with the university faculty.

While we are pleased with the results of our survey and have determined factors from our Noyce program that are important to resilient rural STEM teachers, we understand that our population was small, only 44 people in the PLC with 28 responses. To continue to study the PLC and teacher resilience, we may modify and send out the survey again. It would allow us to look at some alumni responses at two points in time. In addition, more research on teacher resilience has come to light since 2015 when we sent out the original survey. This new research would enable us to fine-tune our survey and dig deeper into components of the ECTR framework that have emerged as more important to our program.

4. Questions from NCES Schools and Staffing Survey

Questions 7 and 8 from the survey focused on their first year of teaching, how well prepared they felt, and what types of support they received. Question 7 asked how well prepared they felt during their first year and aligns well with the ECTR component of "ensure coherence between on-campus courses and the dynamic demands of the profession". Recall that this was one of the components where the Noyce alumni rated the Noyce PLC higher than Teacher Education. We compared the responses of the Noyce and non-Noyce alumni for Question 7. The results are below in Table 4. The Likert scale for this question was: Not At All Prepared (1), Somewhat Prepared (2), Well Prepared (3), and Very Well Prepared (4). From the data, one can see that the Noyce average rating is generally lower than the non-Noyce rating, except for "teach your subject matter". Even then the two-tailed p-value is not less than $\alpha = 0.05$. However, if the alternative hypothesis is posed as the non-Noyce average is less than the Noyce average, the difference is statistically significant, with a p-value of 0.036. In general, it seems that most alumni feel the least confident in their classroom management skills.

Question 8 asked the alumni what types of support they received during their first year. Figure 7 shows that the Noyce alumni receive more opportunities for professional development outside the district, more supportive communication from SDSU faculty, and more regular communication from their administrator. These align well with the following ECTR framework components: "support professional development suitable to the school context", "offered assistance with your teaching and learning beyond your time

at SDSU", and "share responsibility for maintaining positive relationships". Those are three components where Noyce alumni rated the PLC higher than Teacher Education. The results from Question 7 reiterate our findings from the framework. It was pleasing to see that both groups received guidance from a mentor teacher. Most regional districts offer a mentor from the district or through the state mentoring program.

Table 4. Non-Noyce and Noyce results for Question 7.

Question	Non-Noyce Average	Noyce Average	Wilcoxon Rank Sum *p*-Value (Two-Tailed)
Handle a range of classroom management or discipline situations	2.3898	2.1786	0.2090
Use a variety of instructional methods	2.9667	2.7857	0.2836
Teach your subject matter	3.3333	3.6071	0.0719
Use technology in classroom instruction	2.8667	2.9643	0.5488
Assess students	2.8276	2.7857	0.7080
Select and adopt curriculum and instructional materials	2.5932	2.3571	0.2216

Another question from the NCES survey related to resiliency was Question 22, "How long do you plan to remain in teaching?" There were eight possible responses: as long as I am able, until I complete the service requirement for the scholarship/grant I received, until I am eligible for retirement benefits from this job, until a certain life event occurs (marriage, parenthood, etc.), until a more desirable job opportunity comes along, definitely plan to leave as soon as I can, undecided at this time, and I have already left teaching. Three of the eight had zero responses from both non-Noyce and Noyce alumni. The results of their responses are illustrated in Figure 8. The percentage of Noyce alumni who answered "as long as I am able" was 56% compared to 40% for the non-Noyce alumni. We performed a chi-square goodness of fit test, with the three middle categories combined into one category due to low numbers. The hypothesis was that each category would have an equal percentage of respondents. No significant deviation from the hypothesized values was found (χ^2 (2) = 1.769, p = 0.4129). While the percentages indicated that the Noyce alumni may be more committed to teaching, this was not evident from the statistical analysis.

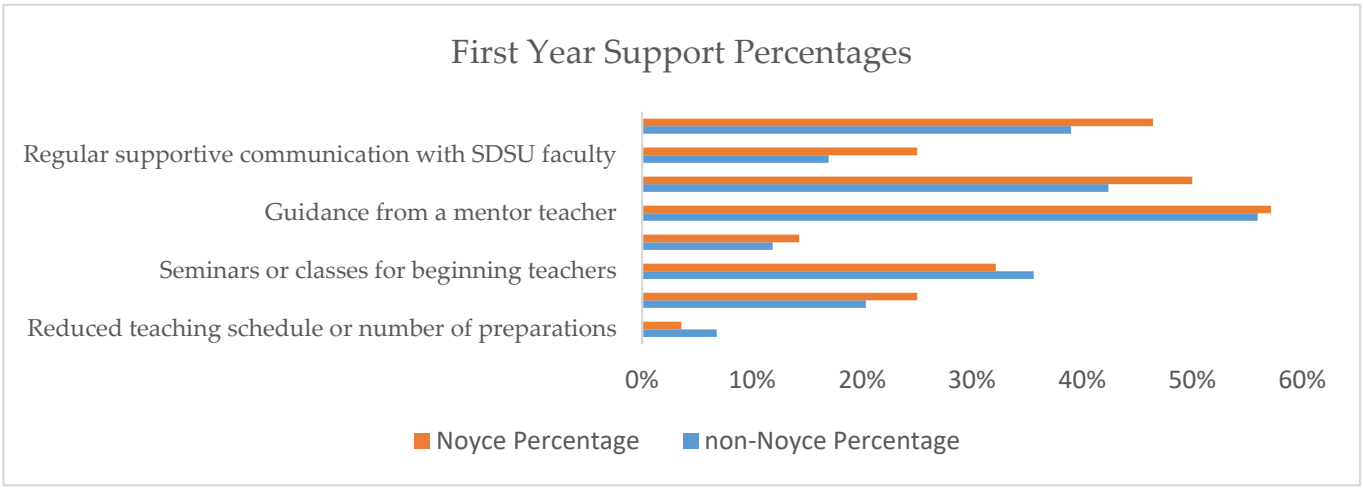

Figure 7. First year support categories for both the Noyce and non-Noyce groups, with the orange bar representing the Noyce group and the blue bar representing the non-Noyce group.

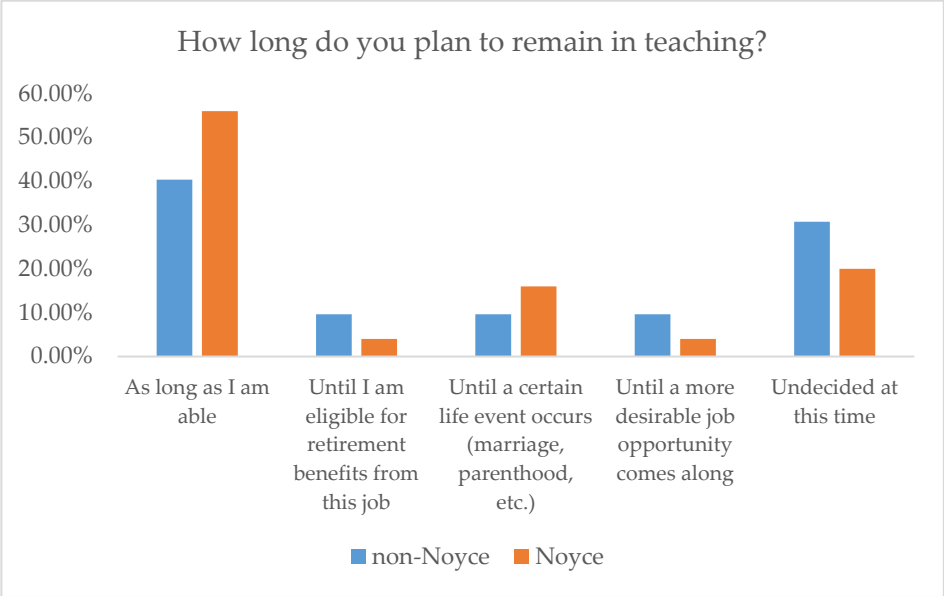

Figure 8. Response percentages for both the Noyce and non-Noyce groups to the question of how long they plan to remain in teaching, with the orange bar representing the Noyce group and the blue bar representing the non-Noyce group.

5. Conclusions

Through our Noyce program, we have created a professional learning community that supports our scholars beyond graduation through the Facebook group and the annual summer conference. These connections give our graduates the confidence to be flexible and handle unexpected situations that occur daily when teaching. They seek support when needed, they offer each other help when asked, and they show courage when faced with uncertainty. When asked if they felt that there was a difference in their preparation as a Noyce scholar, "Selena" said:

> The positive environment that REMAST provides for our teaching helps keep out some of those negative thoughts, negative ideas around teaching and education. So, I feel like sometimes, especially with other faculty it's really easy to look at the negative and only see the negative. Whereas REMAST really tries to focus on the positive and keep on keeping you inspired and growing in your teaching.

Our research confirmed our hypotheses that there was no difference in ratings of the Teacher Education and Major Departments by the non-Noyce and Noyce alumni. However, the REMAST alumni rated the Noyce PLC higher than Teacher Education in about 48% of the components selected from the ECTR framework. These results indicated that the Noyce PLC supported professional development, created a collaborative learning environment, promoted innovation, provided resources for teaching and learning, maintained positive relationships, and helped beyond graduation. These supports provided by the PLC are valued by alumni as seen from the quotes obtained through participant interviews.

How can teacher preparation programs replicate these results? Most students will already be in cohorts, taking classes together throughout their certification program. Universities can make a more obvious effort to build these cohorts into professional learning communities through social networks, book studies, and mentoring. In addition, the key is to remain in contact with the alumni after they graduate. Again, a social network makes this easier, but it is also important to consider alumni surveys to stay in touch and track the graduates through their careers. Our scholarship program conducts an exit interview, asking for relevant information, such as email address, school district, and mailing ad-

dress. Programs should develop a database with contact information and follow up with alumni occasionally. If teacher preparation programs want their alumni to be resilient, they must provide their pre-service teachers with resources and skills to cope with the various demands of a teaching career.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/educsci15010085/s1, Supplementary File S1—Survey Instrument.

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Institutional Review Board Statement: This project is approved as exempt human subject research, IRB-1509015-EXM (28 September 2015).

Informed Consent Statement: Informed consent was obtained from all participants involved in the study through Question 1 of the survey.

Data Availability Statement: Vestal, Sharon (2025). REMAST Resiliency Data. figshare. Dataset. https://doi.org/10.6084/m9.figshare.28136276.v1.

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