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# Exploring science teachers' self-selection attitudes into professional development programs: motivations, preferences, and implications for practice

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**Introduction:** Professional development is essential for science teachers so they can stay current with educational trends, address diverse student needs, and integrate emerging scientific phenomena into their teaching practices. This study explores factors that motivate science teachers to self-select into multi-year-long professional development programs.

**Methods:** The study's sample included 14 exemplary science teachers enrolled in multi-year programs and 58 teachers in one-year professional development programs. Quantitative data were collected from all participants using the Basic Psychological Need Satisfaction at Work Scale and qualitative data were gathered from the multi-year program participants through semi-structured interviews.

**Results:** Grounded in self-determination theory, the quantitative data revealed that exemplary science teachers reported low job satisfaction and significantly lower scores in the *relatedness* construct, indicating they felt undervalued in their workplaces compared to other participants. Qualitative findings supported these results, as teachers expressed their motivations for participating in multi-year professional development programs driven by a desire for personal growth, continuous learning, and a collaborative learning environment, as well as a lack of rigorous in-school professional development options.

**Recommendations:** The results inform recommendations for professional development organizers and educational leaders to prioritize offering sustained long-term professional development programs tailored for exemplary teachers so they can feel supported and valued.

**Conclusion:** The study highlights the importance of tailoring professional development programs to the diverse needs of exemplary science teachers such that they feel they belong in the field of science education.

#### KEYWORDS

professional development, self-selection, self-determination, motivation, exemplary teachers

## 1 Introduction

Educators are considered exemplary when they consistently demonstrate excellent pedagogical practices, dedication, and commitment to teaching and their students consistently show outstanding academic progress (Teacher Incentive and Allotment, 2023). The importance of such exemplary teachers cannot be overstated, as they play a critical role in shaping their students' academic development, and their impact extends far beyond the classroom (Affouneh et al., 2020). There is a consensus that teachers ought to learn and improve their practices continuously through professional learning to remain effective educators and provide high-quality education for all students (Jansen in de Wal et al., 2018; Koh et al., 2016). In alignment with this consensus, according to the Texas Administrative Code, all Texas educators must complete at least 150 Continuing Professional Education (CPE) hours in a five-year period to renew their educator license. These hours can be obtained from various professional development programs, either internally through the school or externally through conferences, workshops, or other PD programs.

While K-12 school districts offer required PD opportunities for teachers, many teachers also participate in non-mandated supplemental PD sessions to enhance teaching practices (Postholm and Boylan, 2018). One example of an external PD opportunity for teachers in the United States is the National Science Foundation (NSF) Robert Noyce Master Teaching Fellowship program. The fellowship, a 5-year commitment, is designed to develop exemplary teachers into teacher leaders in STEM education who remain committed to teaching and staying in the classroom (Vernaza-Hernández, 2020). Participants, also known as Master Teaching Fellows (MTFs), are experienced and exemplary educators with STEM and master's degrees. Such exemplary teachers self-select themselves into fellowships such as Noyce, leveraging their vast expertise to commit to serving in schools with a high population of economically disadvantaged students and inspiring the next generation of STEM learners to develop a passion for STEM education.

There are several reasons why science teachers attend PD programs. Firstly, their needs constantly change, and in-service programs are seen as vehicles for empowerment rather than solely skill development (Juškevičienė et al., 2024; Howe and Stubbs, 1996). Secondly, they desire to increase students' science literacy (Nadelson and Seifert, 2013), align their curriculum with current events such as climate change (Hestness et al., 2014), integrate field studies (Smith et al., 1998), and incorporate technology into the classroom. Thirdly, a high self-efficacy aligned with discontentment in pedagogy influences teachers to seek science

professional development (Saka, 2013), which can address gaps in the competencies of inquiry practices (Akuma and Callaghan, 2020). Fourthly, science teachers, in particular, sometimes feel underserved, as many elementary school principals prioritize reading and mathematics over science (Milner et al., 2012). Finally, the quality of training is a prerequisite for many teachers in determining which PD to attend. Science educators and professional education providers have argued that teachers need multiple opportunities to practice and experience standards-based instruction in their classroom context to change beliefs and instructional practices (Gess-Newsome et al., 2003; Mundry and Loucks-Horsley, 1999). In this study, we aim to further explore the reasons behind science teachers' continuous pursuit of professional development, more specifically of Noyce MTFs.

Understanding these motivations is crucial, as research on the impact of professional development on K-12 science teachers frequently underscores the connection between significant outcomes and factors such as teachers' motivations and their self-selection into PD programs (Fraser, 2010; Gardner et al., 2019; Van Eekelen et al., 2006). Despite a growing body of literature on teacher professional development (Gardner et al., 2019; Howe and Stubbs, 1996; Johnson, 2006; Loucks-Horsley et al., 2009; Mundry and Loucks-Horsley, 1999; Rogers et al., 2006; Blank and de las Alas, 2009; Kennedy, 2016; Rotherham et al., 2008), a significant gap exists in understanding why exemplary science teachers self-select into external long-term PD programs. We understand that teachers vary considerably in how they approach additional professional learning, such that some teachers regularly self-select themselves into outside-of-school PD programs while others rarely participate. Little is known about why some science teachers in large, suburban, diverse areas are likelier than others to participate in optional PD opportunities. Therefore, the aim of the study is to explore the PD needs and preferences of exemplary science teachers from diverse settings and determine effective strategies to support their self-selection into PD programs.

## 2 Literature review

### 2.1 Theoretical framework

This study is grounded in self-determination theory (SDT), which proposes that human motivation can grow from understanding the self and fulfilling personal needs (Ryan and Deci, 2022; Ryan, 2023). It focuses on the characteristics of social interactions and environmental factors that allow those needs to be

met. The theory highlights three essential constructs: autonomy, relatedness, and competence. *Autonomy* refers to the ability of individuals to have control over professional choices (Willner, 1990). Ryan and Deci (2006) further add to the definition of autonomy, stating that it refers to the inherent tendency to make choices, act volitionally, and not be controlled by external pressures. *Competence* relates to the execution of successful behaviors (Ryan and Deci, 2006). For example, science teachers are competent when they believe they can resolve students' real-world issues and when their peers see them as a resource. *Relatedness* is associated with internalized feelings of value, connectedness, and belonging. This relatedness can be with individuals, organizations, content, or self, as individuals have a need to grow these feelings and project them onto others (Niemic and Ryan, 2009). In contrast to the self-efficacy theory idea (Bandura, 1989), which rejects the functional value of autonomy, both autonomy and competence demands must be addressed to maintain intrinsic motivation (Niemic and Ryan, 2009). Together, these three constructs guided our understanding of the self-selection of science teachers into PD programs. Through this framework, we understand that teachers' satisfaction with their basic psychological needs is contingent upon their perceptions of their school work environments. In other words, teachers engage in professional learning if their environments are conducive to such conditions (Jansen in de Wal et al., 2018). Therefore, this paper presents a nuanced view of the characteristics and external factors that influence teachers' decisions to engage in such PD. It also discusses the implications of this research for pre-service teacher education and suggests strategies for cultivating the skills and mindsets associated with ongoing professional growth. By better understanding the factors that drive teachers to seek optional PD, we can ensure that all teachers have the tools and support they need to provide the best possible education for their students.

## 2.2 Adult learning and effective PD

One of the earliest and most influential adult learning theories was developed by Malcolm Knowles, who introduced the concept of "Andragogy" in the 1970s (Knowles, 1970). His theory focused on the differences between how children and adults learn and proposed that adult learners have a self-directed approach to learning that is distinct from the approach children use (Knowles, 1970). Since then, numerous other adult learning theories have been developed, including Transformative Learning, Experiential Learning, and Self-directed Learning. Transformative Learning, developed by Mezirow (2008), focuses on how adults go through a process of profound and permanent change in their thinking due to their learning experiences. Experiential Learning, developed by David Kolb, emphasizes that adults learn best through hands-on experiences and reflect on their experiences to integrate new knowledge and skills (McCarthy, 2010). Lastly, Self-Directed Learning, developed by Allan Tough, proposes that adult learners take responsibility for their learning and seek the resources and support they need to achieve their goals (Merriam, 2001). Together, these theories have deepened our understanding of how adults learn and have informed teaching and learning practices in various fields, including higher

education, professional development, and workplace training. As such, effective teacher PD programs are grounded in adult learning theories and consider adult learners' unique needs, motivations, and experiences (Loucks-Horsley et al., 2009). They provide opportunities for teachers to engage in their learning actively, apply what they have learned to their work, and reflect on their experiences (Zarrabi and Mohammadi, 2024; Blank and de las Alas, 2009). Effective PD programs foster connections (Meyer et al., 2023), where participants not only form communities with others through collaborative activities but also maintain engagement by linking prior knowledge with new information. As teachers are also adult learners, ongoing PD is crucial to improving their teaching practices and staying current with advancements in the education field (Loucks-Horsley et al., 2009). This also requires motivation on their part to continuously engage in the learning process and persist despite challenges. Thus, motivation plays a key role in both adult learning and pursuing teacher professional development.

## 2.3 Types of PD available for teachers

PD programs for science teachers are designed to enhance their knowledge and skills in science teaching, as well as to keep them informed about the latest developments in science education. These programs can take various forms, including internal PD within a school or district that typically focuses on specific topics or skills, external PD such as workshops or conferences offered by universities, professional organizations, or private companies, and online PD (Dunst and Raab, 2010). Effective PD programs are designed with adult learning principles, providing opportunities for self-reflection, collaboration, and application of new learning in the classroom (Darling-Hammond et al., 2017; Meyer et al., 2023). Conferences provide opportunities for teachers to hear from experts in the field, attend presentations on cutting-edge research, and network with other educators (Neubauer and Wesely, 2023). Workshops and courses typically offer more in-depth instruction on a specific topic and may result in certification or other forms of recognition (Oslund, 2016). All such programs are delivered to teachers through various educational institutions such as large universities, education research centers, or other non-profit organizations. Many programs are available through funding from various grant agencies, including the National Science Foundation. Overall, science teachers have access to a wide range of professional development options, both internal and external, to help them stay current on the latest research and best practices in the field.

## 2.4 Self-selection definition

Self-selection is a broad term utilized in various fields and contexts, including workforce development, psychology, statistics, and education. Raveendran et al. (2021) refer to the self-selection-based division of labor as a process where "contributors select for themselves what tasks (or bundles of tasks constituting a 'role' or a 'job') to perform, rather than being assigned to their tasks or job by hierarchical processes." Furthermore, Pike (2006) guides his discussion of self-selection based on Holland's theory of vocational preferences, where self-selection among college students refers to

students choosing a major based on their personality types. In yet another scope, Fresch (1995) refers to self-selection in literacy as “free choice” time where students read books of their own choice. In psychology and research, self-selection refers to the subjects participating in the experiment for “pro-social reasons, wanting to help the researchers, or because of their need for social approval” (Abeler and Nosenzo, 2014). Similarly, for this study, self-selecting teachers refer to educators who regularly opt to participate in supplemental one-day or multi-year-long teacher professional development (PD) programs outside their schools without any formal obligation from their school administrators.

Based on our definition of self-selection, self-selected teachers seek various types of PD programs, including free, stipend-based, and fee-based offerings, on an ongoing basis. We seek to understand what motivates these teachers to continuously seek professional growth and whether certain individual characteristics or external factors play a role. While a study by Feldman (2000) suggests that dissatisfaction with current approaches can drive teachers to seek professional development, we also want to examine other motivators beyond discourse. For example, do teachers seek to gain understanding in areas they were previously unaware of? Additionally, we aim to identify the unmet needs of these teachers and explore their motivations to pursue additional PD. Research shows several barriers teachers face when attending PD, including limited in-service opportunities and inadequate technical support, cultural barriers, and political barriers (Eroglu and Donmus-Kaya, 2021). Teachers need more than just technical training; they require support from district administrators, mentor teachers, and the opportunity to observe other science teachers (Kutsyuruba, 2020) since mentorship from administrators can increase teacher job satisfaction (Tickle et al., 2011).

## 2.5 Research questions

The study aims to address the following research questions:

1. Do the constructs of *autonomy*, *competence*, and *relatedness* at work differ between Noyce Master Teacher Fellows (MTFs) and other PD participants?
2. In what ways do Noyce Master Teacher Fellows (MTFs) describe their reasons for self-selecting into outside-of-school PD?
3. How do the reasons provided by self-selected science teachers for participating in external professional development programs align with the self-determination theory?

## 3 Materials and methods

This study employed a mixed-methods design, incorporating both qualitative and quantitative data collection methods. The quantitative survey, Basic Psychological Need Satisfaction at Work Scale (BPNS-W), is a 7-point Likert scale designed to assess the degree to which teachers' work environment supports their need for autonomy, competence, and relatedness (Deci et al., 2001; Ilardi et al., 1993; Kasser et al., 1992). Understanding the work environment of teachers' schools is critical in aligning

self-determination with self-selection. The survey was administered online using Qualtrics software, and invitations were sent to 160 current science teacher participants of a year-long PD program affiliated with the university to understand their needs at work. A total of 72 teachers filled out the survey ( $N = 72$ ), yielding a response rate of 45.0%.

The qualitative data included one 60-min virtual focus group discussion with four Noyce MTFs ( $N = 4$ ) and triangulated with three additional MTF interviews ( $N = 3$ ), which lasted approximately 30 min each (Carter et al., 2014). Two researchers moderated the focus group and the interviews using a semi-structured guide to explore the participants' motivations for partaking in multi-year-long PD opportunities outside of their school setting. The discussion was audio recorded and later transcribed for analysis using Otter.ai transcription services (Da Silva, 2021). The study was approved by the Institutional Review Board (IRB), and informed consent was obtained from all participants prior to the commencement of the study.

## 3.1 Data analysis

### 3.1.1 Quantitative

We analyzed the BPNS-W survey data and generated descriptive statistics to assess the satisfaction at work of Noyce MTFs and other PD participants for each construct within the self-determination theory (*autonomy*, *competence*, and *relatedness*) and an overall satisfaction score comprising three constructs. We used SPSS to analyze the data, which included reverse coding certain questions and performing independent *t*-tests. The conditions for conducting an independent *t*-test were met: the sample size exceeded 40, the groups of teachers were independent, there were no outliers, the data were normally distributed, and the homogeneity of variances was confirmed by Levene's test. Consequently, an independent *t*-test was conducted to determine the difference between Noyce MTFs and other PD participants' satisfaction at work. Besides the *p*-value, Cohen's *d* and Hedge's *g* were calculated to determine the effect size and its practical significance.

### 3.1.2 Qualitative

The credibility and validity of qualitative data collected were improved by triangulation using focus groups and interviews. Two researchers analyzed the focus groups and interview transcripts inductively using thematic analysis, which involved open coding, axial coding, and identifying patterns and themes in the data as detailed in the book, “Analyzing Qualitative Data” (Gibbs, 2007). Initially, both researchers collaborated on the development of 28 initial codes. Researcher A focused on the open coding process, ensuring a comprehensive identification of potential codes, while Researcher B concentrated on the axial coding phase, where these initial codes were organized into 12 axial codes. Together, they synthesized these into four primary themes that describe reasons for choosing outside-of-school PD. Furthermore, the initial codes were categorized based on SDT constructs of autonomy, competence, and relatedness, and six subtopics related to each construct were developed. Additionally, the researchers purposefully created a “perceived teacher identity” construct to understand teachers' self-perception as educators,



TABLE 1 Percentages of teacher participants at each school level.

	Other PD participant	Noyce MTFs
Elementary school	26%	14%
Middle school	36%	21%
High school	33%	64%
Not provided	5%	0%

as self-knowledge is critical for any professional growth to take place (Bullough, 1989; Gabrys-Barker, 2010). The identity phrases were validated by cross-checking with the original data to ensure each phrase accurately reflected the teacher's responses. To protect against their own biases, the researchers engaged in regular debriefing sessions to discuss and reconcile any discrepancies in their coding.

The qualitative and quantitative data were integrated during the analysis phase. Quantitative results (mean scores and group differences) were compared with the qualitative findings to gain a comprehensive understanding of self-selection teachers' reasons for choosing outside-of-school PD. Patterns, trends, consistencies, and inconsistencies between the qualitative and quantitative data were purposely looked at to provide a more holistic perspective on the research questions.

## 4 Results

Of the 72 teachers completing the Basic Psychological Need Satisfaction at Work Scale (BPNS-W), 14 identified as Noyce MTFs, while 58 participated in other professional development programs. Participants self-disclosed their racial and ethnic demographics, yielding a diverse sample: 18% Asian, 24% Black, 42% white, 17% Other, and 31% Hispanic. While most Noyce MTFs taught at the high school level, the sample spanned all three educational tiers, as detailed in Table 1. Consequently, the study's findings hold relevance across various teaching levels. The following sections report the results for each research question.

### 4.1 Research question 1: satisfaction at work

Table 2 presents the descriptive statistics for the three constructs of self-determination theory—*autonomy*, *competency*, and *relatedness*—among both Noyce MTFs and other PD participants, as gleaned from the Basic Psychological Needs at Work Scale (BPNS-W). Noyce MTFs registered lower scores both overall and within each subscale. To ascertain the presence of significant differences between the groups, we executed independent *t*-tests, which are presented in Table 3.

#### 4.1.1 Overall score

Despite Noyce MTFs garnering lower scores ( $M = 4.86$ ,  $SD = 0.80$ ) compared to other PD teachers ( $M = 5.20$ ,  $SD = 0.81$ ), the independent *t*-test revealed no significant difference in overall satisfaction scores between the groups,  $t(70) = 1.40$ ,  $p = 0.08$ .

TABLE 2 Descriptive statistics for overall and each construct based on the type of teacher participant (Noyce MTF or other PD participant).

	Type of teacher	<i>N</i>	Mean	Std. Dev.
Overall score	Noyce MTF	14	4.8605	0.7967
	Other PD participant	58	5.1969	0.8086
Autonomy	Noyce MTF	14	4.2653	1.2172
	Other PD participant	58	4.5493	1.1947
Competency	Noyce MTF	14	5.4643	1.0299
	Other PD participant	58	5.7213	0.8727
Relatedness	Noyce MTF	14	4.9286	0.7794
	Other PD participant	58	5.3741	0.9426

TABLE 3 2-sample independent *t*-test output between Noyce MTFs and other PD teacher participants.

	Df	T-statistic	<i>p</i> -value	Cohen's <i>d</i>	Hedge's <i>g</i>
Overall score	70	1.4	0.08	0.4191	0.4172
Autonomy	70	0.79	0.21	0.2354	0.2369
Competence	70	0.95	0.17	0.2692	0.2843
Relatedness	70	1.64	0.05*	0.5151	0.4872

\*significant at  $\alpha = 0.05$ .

#### 4.1.1.1 Autonomy

Although Noyce MTFs scored lower on the autonomy subscale ( $M = 4.27$ ,  $SD = 1.23$ ) compared to other PD teachers ( $M = 4.55$ ,  $SD = 1.20$ ), the independent *t*-test indicated no significant difference between the two groups,  $t(70) = 0.795$ ,  $p = 0.21$ .

#### 4.1.1.2 Competency

Even though Noyce MTFs registered lower scores on the competency subscale ( $M = 5.46$ ,  $SD = 1.03$ ) compared to other PD teachers ( $M = 5.72$ ,  $SD = 0.87$ ), the independent *t*-test showed no significant difference,  $t(70) = 0.95$ ,  $p = 0.17$ .

#### 4.1.1.3 Relatedness

In contrast to the other subscales, the relatedness scores revealed a significant difference between Noyce MTFs ( $M = 4.93$ ,  $SD = 0.78$ ) and other PD teachers ( $M = 5.4$ ,  $SD = 0.94$ ), as evidenced by the independent *t*-test,  $t(70) = 1.64$ ,  $p = 0.05$ . Cohen's *d* and Hedge's *g* effect size is approximately 0.5, which is medium.

### 4.2 Research question 2: reasons for choosing outside-of-school PD

To understand the reasons for choosing external PD, it is imperative to understand the participants who took part in focus groups and interviews. Table 4 provides details on Noyce MTFs and the number of years they have been teaching, the number of external PDs they take part in each year, and their perceived teacher identity.

TABLE 4 Noyce MTFs' teaching experience, the number of external PD programs attended per year and their perceived identity.

Pseudonym	School and subject	Number of years teaching	Number of external PDs per year	Perceived self-identity
Sara	HS chemistry	13	6–7	Reflective
Nancy	HS biology	25	2–3	Receptive, resourceful
Annie	ES STEM for GT	17	6–7	Academically driven
Rosie	HS life sciences	20	2–3	Empowered leader
Mary	MS science	11	3–4	Collaborator
Lilly	HS biology	7	1–2	Creative, confident
John	HS science	13	3–4	Energetic learner

GT, gifted and talented students; ES, elementary school; MS, middle school; HS, high school.

In our analysis of qualitative data from seven Noyce MTFs, we identified four primary themes: (i) opportunities for personal growth and continuous learning, (ii) sense of professional community through resource sharing and collaboration, (iii) personal dispositions, and (iv) the lack of depth in internal PDs. See Table 5 for themes and their definitions.

#### 4.2.1 Opportunities for personal growth and continuous learning

MTFs expressed their deep commitment to lifelong learning as the primary reason for seeking out-of-school PD. They value staying current in science. Additionally, engaging in external PD fortifies their energy and enthusiasm for teaching.

- “I graduated a long time ago; science is evolving so I want to remain updated with everything. Also, wanting to learn is a big part of me.”—Rosie
- “Participating in PD rejuvenates you, kind of like why you love teaching.”—Mary

#### 4.2.2 Sense of professional community through resource sharing and collaboration

MTFs related that PD broadens their professional network as they connect with and share resources amongst like-minded individuals. The engagement fosters meaningful collaborations and leads to their personal and professional growth. MTFs leverage their established network within their professional community network to seek exemplary PD opportunities offered by prestigious institutions and credible organizations.

- “PD gave me like a new little network, a new support system that really helped me with learning different ways to get the kids engaged in the work. So, I would say that experience made me wanna come back and learn more. Also, I like the engagement with the network of teachers from different science content areas.”—Sara
- “It’s like you are feeling heard, you are feeling validated because you share ideas with each other.”—Mary
- “I’ve experienced this so many times like [PD] is also a way of networking not just with other participants but also those presenters and some of the presenters that I met, like you know, they are a big resource to me in funding [for school activities].”—Lilly

#### 4.2.3 Personal dispositions

MTFs shared insights into their personal dispositions, describing their personality of embracing opportunities to improve their teaching practice. They like to reflect on their practices and actively pursue opportunities to enhance their pedagogies and strategies. Their main aspiration is to excite and engage the students in their classrooms. Following are quotes that describe their personal identities that correlate with their participation in outside-of-school PD.

- “I am a reflective person. And so that’s the reason why I probably like to attend PD because, you know, I like to reflect on what I’m doing. And anytime I feel like I can improve, I’ll search out ways to do that.”—Sara (Reflective)
- “At this point, my identity as a teacher is kind of sharing with others what I’ve learned. I still try to grow and learn from others and areas that I know I need to improve on.”—Nancy (Receptive, resourceful)
- “I take pride in [taking part in PD] because I feel a sense of accomplishment and because I’m very academic driven. When I learn new things, I take in what I’ve learned and share it with my students.”—Annie (Academically driven)
- “I feel empowered with PD and I realize that I can actually [do things] that I thought I couldn’t. I keep venturing on other stuff so I can serve as a leader.”—Rosie (Empowered Leader)
- “[Participating in PD is] almost like I am feeling heard and feeling validated because I am kind of sharing ideas with other teachers around me who I can like commiserate with about what things work and what don’t.”—Rosie (Collaborator)
- “Attending the PD increases my confidence in the classroom and in my ability to teach. It really sparks creativity in creating lessons, for example.”—Lilly (Creative, confident).
- “I get recharged and reminds me why I am teaching in the first place. I am not only interested in teaching but I am interested in making kids interested in science so [taking part in PD] gives me a blast.”—John (Energetic Learner)

#### 4.2.4 Unmet needs through in-school PD

MTFs detailed the need for outside-of-school PD based on the lack of depth provided at required in-school PDs. MTFs stated that teachers have no choice but to attend the in-school PD as it is required per their contracts. The following are some of the

TABLE 5 Reasons for choosing external professional development opportunities: themes and their definitions.

Theme	Number of initial codes	Definition
Opportunities for personal growth and continuous learning	8	Commitment to lifelong learning and staying current in scientific practices. This includes attending workshops, pursuing advanced degrees or certifications, and actively seeking out new knowledge and skills to enhance their teaching and understanding of science.
Sense of professional community through resource sharing and collaboration	6	Connect and collaborate with like-minded individuals. This theme encompasses the importance of building a network with peers, where they can share resources, exchange ideas, and collaborate with each other in a supportive environment.
Personal dispositions	7	Description of their personality to improve their teaching practice. This includes self-awareness of their teaching style, strengths, and areas for growth, and how personal traits and experiences impact their approach to teaching and learning.
Unmet needs through in-school professional development	6	Identifying gaps or deficiencies in professional development provided within the school setting. This theme explores areas where current in-school professional development offerings may fall short, and what additional support, resources, or training might be needed to better meet their needs.

quotes from MTFs explaining that internal PD is not sufficient for exemplary teachers.

- “Internal PDs that are required by my school are not as exciting. They are not as engaging. It’s like you are just required to go there, just got to sit there, and just got to listen. Some of them are related to content, some of them are not, and it is just taxing.”—Annie.
- “Internal PD is needed at the beginning as you are expected to be able to at least know the content enough to do the bare minimum [as a teacher]. But then when you want to go beyond that, then the other type of PD [external PD] is needed for you to be able to do a better job of helping the students”—Sara.
- “If it’s not specific to my interests or my needs, then I usually don’t find it valuable. you know, often times, the internal PD is just here’s a PowerPoint—somebody is reading it to you and nobody is excited including the presenter. in external PD, there is a high level of engagement, a higher level of willingness to collaborate, to share ideas. Not so much to whine and complain. much more communal and hopeful and optimistic versus just sit here and go through the things.”—Nancy

### 4.3 Research question 3: alignment of self-selection to self-determination

The reasons for self-selecting into PD were then categorized into the three constructs of the self-determination theory, namely *autonomy*, *competence*, and *relatedness*. Within the construct of *autonomy*, the “feeling of choice” and the “love for learning” emerged as the subtopics. Both of the subtopics emphasize a teacher’s control over their own learning and exploration and individually driven decision to take certain PDs. Common themes within the *competence* construct include the desire to become a “better professional as a teacher,” with “high self-efficacy in content and resource sharing.” These two subtopics refer to being proficient

in giving back to their students through sufficient knowledge of their teaching subjects. Subtopics for *relatedness* include the goal of “broadening (their) professional network” and being exposed to “new perspectives.” These two subthemes highlight the importance of having strong connections with other teachers to learn from and collaborate with. Table 6 details the MTFs’ common beliefs and motivations for partaking in external PD based on the constructs of SDT and the quotes from the transcripts that were used to create the groupings. While many teachers expressed similar attitudes, one quote was recorded to represent those sentiments.

## 5 Discussion

Prior research has mainly focused on why teachers attend PD or what makes PD programs effective (Gardner et al., 2019; Howe and Stubbs, 1996; Johnson, 2006; Loucks-Horsley et al., 2009; Mundry and Loucks-Horsley, 1999; Rogers et al., 2006); however, the present study focused on aligning the needs of self-selected PD teachers to self-determination theory.

The first research question aimed to determine whether there are differences in the constructs of autonomy, competence, and relatedness at work between Noyce Master Teacher Fellows (MTFs) and other participants in professional development (PD) programs. By comparing these constructs between the two groups, the question attempted to identify any significant variations in how these factors are experienced and perceived by MTFs versus other PD participants. The satisfaction of basic psychological needs is determined by teachers’ perceptions of their school work environments. Hence, the results of our quantitative data suggest that Noyce MTFs were less satisfied at work compared to other PD teachers, although the difference was not significant. MTFs, being exemplary science teachers, are more dissatisfied with their work environments, which raises questions about meeting their needs. This is consistent with another research study that found that early-career teachers have a higher level of satisfaction with teaching jobs than mid- and late-career teachers (Admiraal and Røberg, 2023). MTFs are considered mid- and late-career teachers since they

TABLE 6 Noyce MTF's views of external PD participation based on SDT constructs.

SDT construct	Subtopics	MTF quotes
Autonomy	Feeling of choice Love for learning	<i>"I choose (PD) based on if I like the content and how much I'm gonna benefit from it. . . is it related to what I'm teaching, what are the take-homes from it."</i> —(Rosie) <i>"I feel like I'm a lifelong learner. I love to learn new things, too."</i> (Annie)
Competence	Better professional as a teacher High self-efficacy in content and resource sharing	<i>"I feel like attending different professional developments would give me something that I can use to do a better job or make the job where it's mostly about, of course, the students"</i> —(Sara) <i>"I discovered that once I'm strong in content then I will know how to validate materials that come to me."</i> (Rosie)
Relatedness	Broadening professional network New perspectives	<i>"So if it's something that other people recommend networking like meeting other people who are also science teachers, biology, teachers and learning from them."</i> (Nancy) <i>"here's an opportunity to actually interact with a set of teachers way out of my norm and seeing what's being done in the other parts of the country."</i> (Sara)

typically have extensive teaching experience. Moreover, mid-career teachers show less enthusiasm about classroom management than novice or experienced teachers because they perceive proficiency in such tasks (Booth et al., 2021; Louws et al., 2017). Noyce MTFs, well-established teachers, have different needs than pre-service or novice teachers and hence require more targeted PD. This suggestion is in accordance with Donaldson et al.'s (2008) research that concluded that experienced teachers take on reform roles and should engage in PD that helps promote this role of a change leader. Similar to career progression in other professional fields, teachers aspire to grow, and this entails embracing the latest innovative practices in pursuit of ultimately contributing to student outcomes (Donaldson et al., 2008). Moreover, when teachers or any adults are motivated to learn, they are more likely to engage in the learning process, persist, and retain new information and skills, leading to better learning outcomes (Gorges and Kandler, 2012). Therefore, to adequately address educators' needs and their motivations to pursue learning opportunities, particularly for exemplary teachers, it is imperative to offer robust PD that caters to teachers' unique needs and their unique professional goals based on their career progress (Louws et al., 2018; Veliz and Mainsbridge, 2024).

Although the overall difference in job satisfaction score was insignificant, the results indicate a significant difference between the *relatedness* score of Noyce MTFs and other PD participants as indicated by a *p*-value of 0.05 and a medium Hedge's *g* effect

size. MTFs had a significantly lower *relatedness* score, indicating that within their schools and at work, they experience a low level of connection, value, and belonging. Belonging, which Fan et al. (2020) described as a sense of being accepted, respected, and receiving social support, is necessary for teachers to perform their work. Educators know the power of belonging for their students; similarly, teachers' need for belonging and value is crucial in increasing job satisfaction (Mérida-López et al., 2022; Yang et al., 2022). This belonging and value come from purposeful opportunities at work to connect with other educators and administrators and engage in open discussions that enhance their teaching practices (Kachchhap and Horo, 2021). When the teachers do not receive such opportunities, it can cause burnout, stress, or decreased engagement (Lavy, 2022). In this regard, Weiqi (2007) states that intention to remain at a job is correlated with job satisfaction and can ultimately affect teacher attrition rate. Therefore, to overcome the feeling of low value and belonging at work, some teachers seek external PD, where they receive opportunities to collaborate with peers and choose to continue networking beyond the duration of the PD program.

The second research question aimed to understand why MTFs engage in professional development outside of their school setting and provide insights into the specific factors that influence their decisions to participate in PD opportunities. The four themes that emerged are discussed below:

**Opportunities for personal growth and continuous learning:** Given that most MTFs have been teaching for more than a decade, they completed their formal education some time ago. They understand the importance of staying current with the advancements in science and thus seek external PD (Ekinci and Acar, 2019; Gorozidis and Papaioannou, 2014). As experienced science teachers, Noyce MTFs' desire to pursue opportunities for personal growth and continuous learning is consistent with a study where researchers observed that early-career teachers mainly focus on growth and improvement in teaching, whereas, mid and late-career teachers (such as Noyce MTFs) have both continuous and growth mindsets, meaning they seek new opportunities to enhance their practices consistently (Louws et al., 2018; Zhang et al., 2021).

**Sense of professional community through resource sharing and collaboration:** MTFs highlighted that taking part in external PD allows them to expand their professional network and colleagues, which positively impacts their teaching practice. They discussed that through these networks, they learn about upcoming PD opportunities, share teaching experiences, and learn from each other, directly benefiting them as teachers and indirectly their students. Moreover, they stated that some of the most effective PDs they attended had built-in components of networking, which were learning experiences they did not receive from instructor-led sessions. Such experiences of networking lead to a collaborative community where teachers feel comfortable sharing their experiences, resources, and ultimately enhance their teaching practices and the overall instructional climate (Juškevičienė et al., 2024; Richter et al., 2025; Rogers et al., 2006; Shand and Goddard, 2024).

**Personal dispositions:** MTFs shared insights into the intrinsic attitudes that drive their professional learning, such as their desire to be "life-long learners," their "reflective personalities," their need for creative resource collaboration, and to be leaders for others (Louws et al., 2018; Zhang et al., 2021). Teachers consistently



engage in opportunities to enhance not just pedagogical skills, but also science content (Ekinci and Acar, 2019; El Nagdi et al., 2018). Reflective personalities allow teachers to take part in comprehensive learning to improve their practice and make it applicable to their classrooms (Ekinci and Acar, 2019; Zarrabi and Mohammadi, 2024). Being collaborative allows teachers to share experiences and exchange ideas of success and failures with peers for the ultimate goal of exciting students toward science (Gardner et al., 2019).

The lack of depth in internal PDs: Although a causal relationship cannot be assumed, we can infer that since MTFs feel less satisfied at work, they seek outside-of-school PD opportunities to meet their individual professional needs. Nevertheless, all MTFs noted the irrelevance of internal PD sessions that they are required to attend at their schools. They voiced their concerns about the limited benefits of internal PD programs compared to the external ones, where they choose to go themselves. They shared that while such programs may benefit novice teachers, experienced teachers often find them lacking in meeting the unique needs and demands of their classrooms. MTFs encounter challenges in achieving differentiated PD at the school and district levels, which results in MTFs actively seeking external PD opportunities (Ekinci and Acar, 2019). These thoughts are similar to previous research findings, which consistently highlight that teachers often perceive traditional PD as irrelevant or misaligned with their unique needs (Darling-Hammond et al., 2017; Zhang et al., 2015). This misalignment of internal PD programs leads to disconnection, which could mean lower relatedness scores for MTFs and their feeling of being unsupported in their professional growth (Belay and Melesse, 2024). Therefore, the implication for school administrators is to ensure that the professional needs of experienced science teachers are not missed. If schools cannot provide targeted and specialized PD to experienced science teachers, they should collaborate with educational institutions that provide such PD. The partnership can help ensure that experienced teachers grow professionally and are retained in the teaching profession.

In sum, our findings indicate that teachers, particularly exemplary science teachers, engage in external PD to advance their professional growth, nurture their personal identities, appreciate the sense of professional community fostered by PD, and in response to the lack of comprehensive internal PD opportunities.

Research question three aimed to investigate how the reasons provided by self-selected science teachers for participating in external PD align with self-determination theory. Self-determination theory posits that motivation is driven by three basic needs: autonomy, competence, and relatedness. By examining the alignment of self-selected STEM teachers' motivations with self-determination theory, we can better understand the underlying psychological factors that drive their participation in PD opportunities.

Alignment of self-selection and self-determination: Both of these concepts are closely aligned in the context of professional development for science teachers. *Self-selection* refers to the voluntary nature of teachers' decisions to participate in specific PD activities, while *self-determination* refers to the extent to which teachers have control over their own lives and actions related to teaching and can fulfill their personal and professional needs and goals. In the case of science teachers who self-select into PD opportunities, they exercise their autonomy and make choices

that align with their personal needs, interests, and goals (Belay and Melesse, 2024). This is consistent with the core tenets of self-determination theory, which proposes that individuals with a sense of autonomy, relatedness, and competence are more likely to be intrinsically motivated and engaged in professional activities (Niemiec and Ryan, 2009). By self-selecting into PD programs aligned with their interests and needs, science teachers are more likely to be engaged, motivated, and effective in their teaching practices. The section below discusses the three constructs of SDT, *autonomy*, *competence*, and *relatedness*, and aligns them with the self-selection attitudes of teachers as described in Table 4.

Regarding *autonomy*, MTFs expressed their willingness and choice to participate in external PD due to their interests and needs, devoid of coercion or compulsion. Based on the qualitative data analysis, *autonomy* was divided into two subtopics: "feeling of choice" and a "love for learning." The ability to make choices augments the level of autonomy in a person (Núñez and León, 2015). Likewise, the MTFs consistently utilized their "feeling of choice" to determine which external PDs to attend. Besides having the choice, another theme that emerged from MTFs' discussion was their "love for learning." The inclination to learn new concepts and keep up to date with the evolving educational trends was one of the factors that pulled the MTFs toward taking part in external PD. MTFs shared that after partaking in PD, their "love of learning" gets transferred to their students, leading to an excitement for science among their students. Having autonomy in their professional growth is positively associated with teachers' motivation and their ability to bring engaging approaches to their classrooms. Our findings align with another study, which established that when teachers feel their autonomy in decision-making is undermined, it negatively impacts the enthusiasm and creative energy they bring to their classrooms (Belay and Melesse, 2024; Kunter and Holzberger, 2014; Niemiec and Ryan, 2009). Therefore, to safeguard experienced science teachers' autonomy, it is imperative to support them in their professional growth, ensuring their enthusiasm to teach and learn remains intact. One interesting finding to note is that teachers feel coerced to participate in internal, required PD at schools, which, as indicated by the discussion of research question 2, often fails to align with their needs. Consequently, in the absence of such autonomy about choosing PD within the school setting, MTFs, who are exemplary science teachers, seek external PD and embrace the opportunities to enhance their own learning and, as a result, ignite their students' enthusiasm for science.

In regards to *competence*, MTFs expressed their desire to improve their skills and pedagogical strategies and share new resources with the students. Based on the qualitative data coding, *competence* was divided into two subtopics: "better professional as a teacher," and "high self-efficacy in content and resource sharing." MTFs consider themselves "life-long learners" with reflective personalities. They seek external PDs to satisfy their desire to become better professionals and gain confidence (Belay and Melesse, 2024; Song and Zhou, 2020). Additionally, MTFs understand that the schools often do not have adequate resources to support them as science teachers, prompting them to seek outside-of-school PD. The external PD allows them to gain valuable resources and benefit from them while allowing them to become better professionals as teachers (Song and Zhou, 2020). In fact, one MTF highlighted that through external PD, she connected with an

individual who could fund some of the activities at her school. Lastly, MTFs noted that participating in external PD increases their self-efficacy in science teaching (Song and Zhou, 2020; Rich et al., 2021). As teachers progress in their teaching experience within classrooms and from taking rigorous PD, teachers' thinking levels become more sophisticated. To develop competence in teaching science, teachers can be considered as adaptive experts who continue to look for ways to gain more knowledge and develop new ways of thinking to become better professionals, utilize the resources, and become self-confident in their teaching practices and ultimately impact the students positively (Schneider and Plasman, 2011; von Suchodoletz et al., 2018).

Based on the qualitative data coding, relatedness was divided into two subtopics: "broadening professional network" and "new perspectives." MTFs related that participating in external PD offers them opportunities to both "broaden their professional network" and benefit from the support of this network. Previous studies have underscored the advantages of having a strong and supportive network of colleagues and administrators for teachers (Borko, 2004; Rogers et al., 2006; Snow-Gerono, 2005). Thus, this network is one of the key pull factors for MTFs to attend external PDs. Such networks are beneficial for MTFs to connect with like-minded individuals, learn about future PD opportunities, and find new ways of teaching (März and Kelchtermans, 2020; Rogers et al., 2006). Additionally, MTFs highlighted that by attending PDs, they see "new perspectives" from their peers, learn new ways of teaching the same concepts, and, thus, learn from each other extensively. They gain new skill sets and hear from experts at PD programs that increase collaborative partnerships (Borko, 2004; Taylor and Govan, 2017).

Similar to how MTFs showed a significantly lower *relatedness* score compared to other PD teachers, in the qualitative data, MTFs highlighted that the network of science teachers at their respective schools is not large, and the PD provided is not relevant to them. MTFs reported that they seek external PD because of the possibilities of broadening their professional networks and having supportive colleagues from various backgrounds. Therefore, there is an implication for school administration to provide relevant PD to experienced science teachers and allow them to expand their professional network by building communities of practice beyond their respective schools (Borko, 2004; Shand and Goddard, 2024). Additionally, administrators can work closely with teachers and encourage them to attend PDs that help motivate them and increase their leadership activities (Birky et al., 2006).

## 5.1 Theoretical contribution

This study contributes to the literature on professional development for exemplary science teachers in various ways. First, this research advances our understanding of motivations behind exemplary science teachers', particularly Noyce MTFs', self-selection into multi-year-long PD programs. By exploring their motivations, this study extends self-determination theory's implications to long-term teacher development (Schneider and Plasman, 2011). Second, through the empirical evidence of external PD programs' benefits for Noyce MTFs, this study affirms the need for PD programs designed specifically for experienced and exemplary teachers so

such teachers can become leaders in their classrooms, schools, districts, and nationwide. Such programs are urgently needed to empower and retain experienced teachers in the education systems. Retention of such experienced teachers is paramount to the stability of education as many late-career experienced teachers leave the profession due to burnout, lack of support, or feelings of stagnation (Louws et al., 2018; Lavy, 2022; Zhang et al., 2021). Providing exemplary science teachers with ongoing opportunities for growth not only reinvigorates their passion for teaching but also imparts a sense of value and recognition. These findings inform the PD developers to promote self-determination and intrinsic motivation among self-selected science teachers and foster a supportive community, offering mentorship and creating platforms for knowledge exchange among teachers to enhance their overall well-being, sense of value, belongingness, and job satisfaction (Darling-Hammond et al., 2017; Mérida-López et al., 2022; Yang et al., 2022).

## 5.2 Limitations and further research

Knowing the researchers were affiliated with the PD developers, there is a possibility that Noyce MTFs spoke highly of the PD to maintain their credibility as program participants. Additionally, because the participants chose to participate in the PD voluntarily, they may be more motivated to improve their teaching practice than other teachers who did not participate. This could introduce a bias in the findings, affecting the generalizability of the results to the broader population of teachers. Lastly, this study lacks qualitative data from other PD teachers regarding their participation in PD programs, and therefore, to effectively compare Noyce MTFs and other PD participants, future works should aim to include focus group discussions and interviews with other PD participants (Borko, 2004; Lieberman and Pointer Mace, 2008; Zhang et al., 2015).

## 6 Conclusion

The crucial significance of professional development cannot be ignored; however, it must be thoughtfully designed, considering the varying needs of science teachers, including novice, experienced, and exemplary teachers. Using the self-determination theory, in this study, researchers took a unique approach to understanding the needs, attitudes, and motivations of self-select science teachers, particularly Noyce MTFs. The study's findings have profound implications for school district administrators, PD developers, educational researchers, and teacher educators, emphasizing the importance of targeted and relevant PD programs that cater to different teacher groups and the importance of the feeling of belongingness in the workplace. By understanding the needs and identities of self-selected teachers presented in this study, PD developers should work on cultivating mindsets of professional learning in pre- and in-service teachers. School districts should expand their PD programs or collaborate with organizations that deliver high-level PDs to provide targeted PD and ensure maximum impact. This strategic approach will enable educators, particularly experienced science teachers, to access training that aligns with

their unique needs, ultimately enhancing their professional growth and effectiveness in the classroom.

## 6.1 Recommendations

Based on the findings of the study, here are some key recommendations for PD developers and education leaders:

- Design tailored PD programs that address the specific needs of different teacher groups, including novice, experienced, and exemplary. Providing opportunities that recognize and leverage the expertise of exemplary teachers is essential to supporting the professional growth of all teachers.
- Create supportive PD environments where teachers feel valued and empowered. PD should foster a culture of continuous improvement within schools and contribute to enhancing teachers' job satisfaction.
- Rather than offering one-time workshops, PD should be an ongoing process. By offering sustained support and opportunities for reflection, teachers can effectively integrate new knowledge into their classroom practice.

## Data availability statement

The datasets presented in this article are not readily available because of privacy concerns of the research participants. Requests to access the datasets should be directed to FZ, [fz25@rice.edu](mailto:fz25@rice.edu).

## Ethics statement

The studies involving humans were approved by the Institutional Review Board, Rice University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

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## Author contributions

FZ: Conceptualization, Data curation, Formal Analysis, Investigation, Writing – original draft. CA: Conceptualization, Investigation, Methodology, Writing – review and editing. CN: Funding acquisition, Supervision, Writing – review and editing. ST: Data curation, Visualization, Writing – review and editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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