Mentoring and Motivation: Examining Teachers' Immersive Research Experiences via Self-Determination Theory

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Abstract

The present study examines motivational aspects of science teachers' engagement in a professional development (PD) program during an immersive mentoring program. Teachers from high-poverty schools were selected into the program, particularly novice teachers, women, and individuals from minority groups. Self-determination theory (SDT) was used to frame the findings and to analyze teachers' data collected via focus groups and individual interviews. Overall, the study findings describe the array of teachers' motivations and values for the program. In addition to generic motives and values, the results provide significant understanding of the SDT's key components, such as competence, autonomy, and relatedness. Findings suggest that teachers placed importance on experiences that provided them with feelings of competence (e.g., ability to successfully complete the tasks), autonomy (e.g., flexibility in choice of tasks and level of engagement), and relatedness (e.g., ability to connect with peers and mentors in the process of learning). These findings have numerous implications for PD program design and for teachers and administrators.

Keywords: STEM, professional development, immersive science, self-determination theory, motivation

Introduction

Providing quality and novel professional development opportunities for teachers in science, technology, engineering, and mathematics (STEM) areas is crucial, particularly for novice teachers working with underrepresented populations in STEM (Hubbard et al., 2024; Thomson et al., 2021). With the rapid advancements in the global economic and technological climate, there is a growing need for STEM workers (Chiu, 2024; Mara & Thomson, 2021; Milfort, 2012), and the past decade has been marked by strong national efforts geared toward preparing students for STEM careers (Ball et al., 2017). Students from underrepresented populations in STEM have been the target of nationwide initiatives to encourage greater representation in these domains (Aish et al., 2018).

According to the National Science Foundation's report (NSF, 2017), the main underrepresented populations in STEM have been women and racial/ethnic minorities, including Black or African

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American, Hispanic or Latino, and American Indian or Alaska Native individuals. Additionally, individuals with disabilities are also underrepresented in the STEM workforce, the report specifies. These groups are underrepresented in STEM occupations compared to their share of the overall working-age population. According to NSF (2017), underrepresented populations accounted for about 20% of STEM degrees at the undergraduate level, 14% at the master's level, and 8% at the doctoral level, and represented 12.7% of the entire STEM workforce. Research shows that teachers working in schools with underrepresented, economically disadvantaged students often lack the instructional resources and specific professional development (PD) opportunities to better prepare their students for STEM careers (Thomson, 2024). Additional research findings show that PD programs that provide immersive research experience and involve teacher participation in university laboratory, inquiry-based activities, were positively correlated to teachers' motivations and emotions regarding their PD experiences as well as changes in practice in the classroom (Hubbard et al., 2022; Gorozidis & Papaioannou, 2014; Thomson & Turner, 2019). Furthermore, research findings on teacher programs focused on providing K–12 teachers with immersive research-based science experiences attest to significant changes in teachers' classroom practices toward a more inquiry-based approach, thinking like a scientist, and motivating students to engage in science learning (Lee & Blanchard, 2019; Pelletier et al., 2002).

The present study examines the nature of motivation among science teachers, particularly those working in schools with a high number of underrepresented students, within the bounded context of a PD program. The current study is part of a larger longitudinal research study from a 5-year project funded by the National Institutes of Health (NIH). In this program, novice teachers participate in mentorship research experiences with scientists from a major research university in the United States. The mentorship program allows teachers to work alongside scientists to learn research science skills and knowledge in the environmental health research science area. There are three factors that are helpful to our study's purpose. Firstly, participation in the PD program is voluntary. Teachers in the current study were therefore participating of their own volition. Secondly, most participants identified themselves as members of minority groups, thus as underrepresented populations. They were from schools with a large number of students identifying as well as being part of a minority race/ethnicity. Additionally, the teacher participants in the current study worked in schools with a rate of 75% and higher of students with free and reduced-price lunch (FRPL), thus being considered economically disadvantaged students. Thirdly, science teachers benefit from programs that are constructed around important areas of their motivation, such as utility value/relevance for the program, relatedness, mentoring, and working in an immersive program in an authentic lab environment. Knowledge about teachers' motivations will provide critical input that can inform future PD program designs that are ultimately geared toward enhancing science learning experiences for underrepresented populations. The current study, therefore, has implications for PD program developers, researchers, administrators, teachers, and their students. The research questions that guide this study are as follows:

1. What general factors motivate teachers to participate in an immersive-science PD program?
2. What psychological needs contribute to teachers' motivation to enhance students' science learning experiences?

Theoretical Framework: Self-Determination Theory (SDT)

Intrinsic motivation arises from the human need to be competent and self-determining in relation to the environment. Intrinsic motivation energizes human behavior and the will to satisfy needs. When individuals are intrinsically motivated, they engage in tasks because these are perceived as interesting and enjoyable. In contrast, when individuals are extrinsically motivated, their actions are influenced

by some separable, externalized outcome. Extrinsic motivation can be internalized, whereby a person integrates the value of the activity into their own goals (Ryan & Deci, 2000).

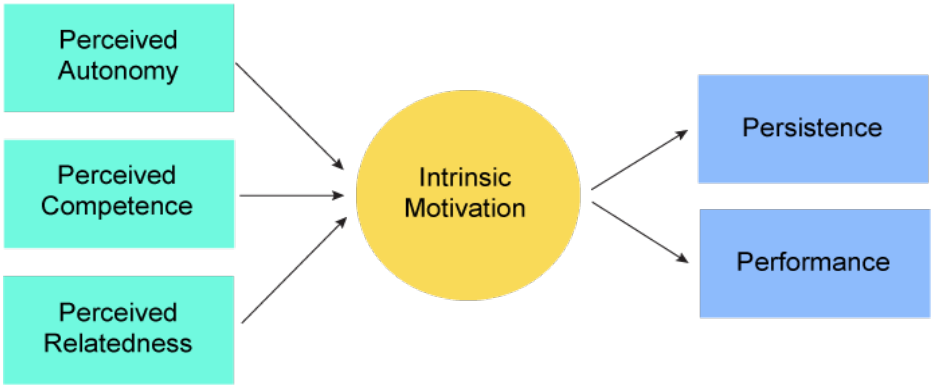
According to SDT, one of the most influential contemporary motivational theories, people are intrinsically motivated when their needs for *autonomy*, *competence*, and *relatedness* are met (Ryan & Deci, 2000). *Autonomy* constitutes a feeling of overall psychological liberty and provides the learner with a sense of freedom, allowing for choices and flexibility in performing tasks. SDT makes the distinction between *autonomous motivation* and *controlled motivation*. Research shows that *autonomous motivation* has been positively related to well-being and satisfaction. Conversely, *controlled motivation* has been positively associated with less desirable consequences such as depression, anxiety, and negative emotions (Turner, 2023). With autonomous motivation, a person operates from a place of interest, enjoyment, and value, whereas with controlled motivation, a person's behavior is influenced by demands and obligations (Ryan & Deci, 2000).

Competence conveys a feeling of control over the outcome and a sense of mastery, giving the learner a sense of satisfaction when the task or a performance is successfully accomplished. SDT places great importance on the role of feedback in enhancing motivation, persistence, and quality performance. Providing positive feedback on a task has the potential to increase intrinsic motivation and decrease extrinsic motivation for the task. On the other hand, negative feedback has the opposite effect, decreasing intrinsic motivation by undermining the individual's need for competence (Deci, 1980).

Relatedness constitutes a feeling of belonging and the need to interact with others or be connected to other individuals. The fulfillment or dissatisfaction of relatedness can either promote psychological functioning or can undermine it through deprivation. Providing positive learning contexts with nurturing social environments can significantly increase intrinsic motivation and performance (Deci, 1980).

For teachers, a professional context that is caring and cohesive is significant to teacher motivation (Richardson et al., 2014). Based on SDT, we can target teachers' motivation by creating situations and opportunities that support their psychological needs. Figure 1 presents the key components of the SDT: autonomy, competence, and relatedness.

Figure 1. *Key Components of Self-Determination Theory*



Note. Adapted from Deci & Ryan, 2000

Literature Review

Fostering Motivation for PD programs

Understanding teachers' motivation and teaching choices is imperative to understanding how to best connect students to science content. Students learn science best when they feel confident,

comfortable, and capable (Bernaus & Gardner, 2008; Chiu, 2024). In some ways, students' motivation to participate and engage is tied to their perceptions of teachers' support and control (Jang, 2008; Jang et al., 2010; Mara & Thomson, 2021; Reeve & Jang, 2006). Being increasingly responsible for developing students' interest in science, providing students with autonomy to connect with science content, and empowering them to pursue their interests in STEM fields puts teachers at risk of feeling unmotivated or lacking the materials and resources to accomplish all of this.

Researchers examining various PD experiences for teachers underline the importance teachers place on their autonomy. One key aspect related to teachers' willingness to implement changes to their instruction is their perceived sense of *autonomy*. Providing teachers with a sense of autonomy and flexibility in their work has been strongly related to increased motivation and job satisfaction (Davis & Wilson, 2000; Gorozidis & Papaioannou, 2014). Similar findings show that changes to teachers' beliefs and practices were mainly related to teachers' values and relevance of the PD program attendance. The findings also highlighted that there may be little motivation for teachers to implement the newly gained PD knowledge into their classrooms if they don't have the autonomy and support from colleagues and administration in introducing the new instructional approach (Hubbard et al., 2022; Patall et al., 2017).

Further research findings show the importance of PD programs that provide teachers with *perceived competenc*e and relevant experiences (e.g., utility value for the programs). Findings recognized that teacher motivation for attending a PD program or continuing to attend was associated with perceived relevance, and ability to transfer knowledge from the PD program into the classroom (Guskey, 2003; Hubbard et al., 2024). Additional research investigating teachers' motivations and values for attending PD programs showed that teachers' key reasons for engaging included intrinsic motivators (e.g., personal and professional interest), gaining new instructional ideas, and improving their instructional skills (Hubbard et al., 2022; Thomson, 2024).

The literature on both teacher and student motivation appeared to emphasize the role of social relationships and *relatedness* as a motivator for teachers' learning and implementation of knowledge (Korpershoek et al., 2020; Palermo & Thomson, 2018). Researchers examining teachers' experiences in mentorship programs show that teachers' thoughts, attitudes, and practices in the classroom are greatly influenced by the social and emotional context (Thomson et al., 2021). Building professional networks and benefiting from the strong emotional connections with their peers represented a key aspect in teachers' motivation and program satisfaction as related to their professional development (Thomson & Turner, 2019). Additional studies revealed themes that suggested individual relationships were a critical transformational leadership behavior, and through relationships, school leaders can encourage teachers (Barnett & McCormick, 2003; Mara & Thomson, 2021).

Supporting Active Learning via Inquiry-Based Strategies

Twenty-first-century science education reform calls for changes in the way science is taught in K–12 classrooms. At the core of this shift in pedagogical approach, students inquire about their everyday worlds, deepening their knowledge through self-directed investigations, connections to their experiences, and developing justifications and theories (Armbruster et al., 2009; Thomson et al., 2024). Inquiry is viewed as essential to student learning, and it is intended to foster critical thinking and problem-solving aptitudes (English & Kitsantas, 2013; NSF, 2017).

Many science teachers have not had authentic research experiences in the content areas that they teach and may have only experienced lecture-style classes within these disciplines; this creates an issue, as educators often mimic the pedagogical styles in which they were taught. Therefore, providing teachers with authentic lab experiences in their content area and a mentorship approach to learning science helps teachers develop quality-based instruction by transferring the experiences to students (Donnelly, 2010; Furtak & Kunter, 2012; Rebull et al., 2018; Thomson, 2024).

A key priority for science teachers' using inquiry-based teaching methods is the facilitation of meaningful student experiences (NSF, 2017). It is well documented in the literature that there are core challenges for many teachers trying to implement these methods. Teacher training has been suggested as an effective way to increase teachers' motivation and readiness to adopt new approaches, such as inquiry-based teaching, into their practice. Providing teachers with authentic experiences that engage them in active learning supports the development of inquiry-based skills and knowledge necessary for effective science teaching (Capps et al., 2012; Lotter et al., 2016; Weng et al., 2022).

Methods

Research Design

The current study describes an instrumental case study (Creswell & Poth, 2018) of one cohort of teachers participating in an 8-week science-immersive PD program. Merriam (1988) suggested that a case study "offers insights and illuminates meaning that expands its readers' experiences. These insights can be construed as tentative hypotheses that help structure future research; hence, the case study plays an important role in advancing a field's knowledge base" (p. 32). An instrumental case study was the most suitable qualitative method for this work because its focus is to understand teacher motivation with a consideration of a critical implication—to guide the structure for future research in PD that will better align with teachers' motivational needs. Further, the case study approach was selected because the study takes place within the bounded context of an 8-week PD program (Creswell & Poth, 2018; Denzin & Lincoln, 2005).

Research Context

In the current study, participants attended an 8-week summer research mentorship program working with scientists in research laboratories at a large R-1 institution in the United States. The research labs hosted the teachers and provided support for their learning in topics related to environmental health research science. Each lab had a different focus and expertise in the field; thus, teachers were exposed to a variety of research areas in this program. Teachers were engaged in the immersive science summer PD program following a voluntary agreement to host and mentor one teacher participant for an 8-week period. The labs were compensated for the costs of materials used by the teacher participant for the duration of the program. Participants' assignment to their host mentor lab was based on pairing with labs that most closely matched participants' interests, experience, and the courses they expected to teach upon returning to their schools. Each week for four days, participants reported to their assigned mentor lab to function as an active member of the lab's research team. Participants' research activities were generally based on the research projects being undertaken by their host labs. One day per week, participants joined together with other research teacher participants and the PD program research team for guest lectures, networking, and focus group sessions. On average, participants committed to 40 hours per week in these PD-related activities. At the end of the program, participants were invited to present their individual research findings in a public symposium.

Participants

In the current study, the participants ($N = 8$) were all female high-school science teachers who taught in public schools. The study participants, who were the first cohort of the PD summer program, were recruited through emails and referrals from school administration. Each year, eight teachers were selected into the PD program (based on the allocated project's funds). Teachers interested in the program could apply to an online application that asked basic questions about the school district, teaching experience, and interest in research. The criteria for acceptance into the program are as follows: 1) teachers who taught in public schools with high-poverty levels (e.g., large number of

students qualifying for the Free and Reduced Price Lunch (FRPL) and students; 2) novice teachers, namely teachers who had less than 10 years of experience in teaching science, and 3) teachers who expressed interest in conducting lab research. In particular, women, individuals identifying as members of a minority group, or teachers of underrepresented populations, as well as individuals with disabilities, were encouraged to apply. The total number of participants in the program was eight; all were female, and most of them (7 out of 8) identified themselves as individuals of a minority group (e.g., African American). Participants' teaching experiences were under 10 years, with the exception of three participants. Although the program recruited novice teachers, due to the small number of applicants in the first year of the project, it was decided to relax the inclusion criterion on years of teaching experience. Participants' pseudonyms and teaching experience are shown in Table 1.

Table 1. *Teacher Participants' Demographic Features and Subjects Taught*

Participant	Race	Gender	Yrs. teaching	Subjects taught
Blake	AA	F	5	Physical science
Dylan	AA	F	18	Biology, physical science, earth science, AP biology
Gabi	AA	F	20	Anatomy, biology, physical science, forensics, AP environmental science, AP chemistry
Jay	AA	F	4	Chemistry, biology, physical science
Kori	W	F	3	Biology
Pat	AA	F	5	Physical science, biology, chemistry, AP biology, health, biomedical science
Rori	AA	F	4	Career and technology education, environmental science, biology, biomedical science
Trey	AA	F	24	Chemistry, physical science, physics, earth science

Note. AA = African American, W = White, F = Female

Data Collection

The data set analyzed for the current study included focus groups and individual interviews with all study participants at different time points during and after their completion of the PD program. One member of the research team moderated the focus groups while the data were recorded and transcribed by another member of the team. The individual interviews were conducted and transcribed by two research team members. Descriptions of the data sources follow.

Focus Groups

A total of two focus groups were conducted during the 8-week PD program. All eight program participants took part in the focus group interviews during the summer program. One focus group was completed at the beginning of the program (in the second week), and the second focus group was conducted at the end of the program (within the last week of the program). The purpose of the focus

group sessions was to capture teacher participants' general feelings and experiences in their individual labs. These focus groups were also conducted as a general, informal opportunity for feedback about the program and possible changes that could be made for improvements (see Appendix A).

Individual Interviews

In-depth interviews were conducted at the end of the first academic semester, about 5 months after the PD completion, when teachers were back in the classroom. Participants were contacted via email, and a telephone interview was scheduled at the participant's convenience. Each interview lasted approximately 30 minutes. Interviews were recorded digitally and later transcribed (see Appendix B). Interview data analyzed in the current study were available from six participants only, as two participants (out of the initial eight) were unavailable to complete the individual interviews.

Data Analysis

Data analysis for the current study was guided by the *six phases of thematic analysis* put forward by Braun & Clarke (2006). The following describes the data analysis process for each of the six phases.

Phase 1

The first phase of data analysis included familiarizing oneself with the participants' study data. This involved organizing and transcribing the recordings, as well as actively reading transcripts repeatedly to identify patterns and meanings. This process was also applied to all transcripts to identify surface-level connections across data sources. At this stage, the focus of analysis was on open coding and identifying categories across the data.

Phase 2

The second phase involved reviewing the data for features that connect with the research question. Excerpts were organized into meaningful groups with the assistance of ATLAS.ti version 8, a computer-based software. At this phase, an inter-coder agreement was performed between the two coders (each coder independently coded data), based on an initial code book that was developed (Appendix C). For coding purposes, each interview was divided into segments, and the task was for the coder to apply the codes to the segments.

Based on the coding performed on the interviews by the two coders, a percentage agreement was calculated. The percent agreement method from Miles & Huberman (1994, p. 64) was adopted as the main formula for calculating intercoder agreement:

$$\text{Intercoder Agreement (\%)} = \frac{\text{Number of Agreements}}{\text{Number of Agreements} + \text{Number of Disagreements}} \times 100$$

A total of 9 codes were identified by both coders; of these, 7 met agreement, resulting in 77% intercoder agreement. Some codes were revised based on this exercise. The code "Positive communication with others" was eventually merged into "Supportive relationships." Other codes that were unrelated to the research questions, such as "Length of time in school county," were removed.

Phase 3

The third phase of thematic analysis involved organizing the codes into larger groups. Using the SDT framework, the larger groups were labeled to reflect the theoretical framework, namely autonomy, competence, and relatedness. Codes that did not fit into a theme were grouped into "emerging themes" (e.g., expectations, values).

Phase 4

The fourth phase involved reviewing the themes. The theoretical framework was consulted at this point to further form connections between the codes and the existing codes. The modified codes were sorted into the three guiding categories: competence, autonomy, and relatedness. Within these three categories, the next step was to examine the codes for patterns, which eventually yielded the themes for the study's findings.

Phase 5

In the fifth phase, theme definition consisted of applying excerpts from the data to the key themes to better connect the meaning of the teachers' narratives.

Phase 6

In the last phase of data analysis, a review of the key themes and how they aligned with study findings was performed.

Results

The current study examined teachers' motivations as related to their participation in an immersive science PD mentorship program. Participants' data were analyzed with the aim of unpacking evidence of their motivation, particularly aspects related to their perceived sense of competence, autonomy, and relatedness, and exploring its nature.

General Motivation Factors

The first research question investigated *motivational factors associated with teachers' participation in an immersive-science PD program.* Findings show that, generally, teachers' motivation to participate in the program was hinged on enhancing their students' science learning experiences. Data analysis revealed three driving factors describing teachers' generic motivation for attending the PD program. The factors described in this section indicate that teachers were generally motivated by a desire to learn more about environmental health research and to *strengthen* their science curriculum. In addition, they were motivated to apply the knowledge they had gained in the lab to classroom teaching, thereby transferring it to students. Finally, they were motivated to acquire appropriate science equipment to enhance their science teaching. The following themes describe the generic motives that teachers expressed: *strengthening the curriculum, transferring their knowledge to students, and acquiring resources for their classrooms.*

Strengthening the Curriculum

The objective of *strengthening the curriculum* was evidenced by participants in their statements about wanting to gain more scientific knowledge and incorporate it into their curriculum. In particular, participants mentioned that they pursued PD programs that offered specialized science knowledge, not just general science content. The current NIH program that teachers attended focuses on environmental health research science, an area that is scarcely explored in the high-school science curriculum. One participant, Dylan, shared her reasons for participating in the summer program: "I've tried to find something in the summer that will also help with my curriculum. I was looking for ways to teach science and make it more interesting to them (n.r. her students)." Other participants spoke about the research experience as a way of providing insight to their students about working in a lab and conducting scientific research. Rori, one of the program participants, shared:

> I didn't know all of this stuff about plant structures. I've only taken like one botany class, so I didn't know all this stuff. It's good to learn new things, and I really do feel like I can bring

> this back to my environmental APES (AP Environmental Science) class because the research we are doing kind of directly correlates into environmental issues.

Transfer of Newly Gained Knowledge

An important aspect present in participants' interviews and focus groups was their appreciation for the opportunity to learn about research in a field that was novel to them, and consequently, having the ability to take their *newly gained knowledge and skills and transfer it into their classrooms*. The immersive experiences in the PD program allowed teachers to work daily on ongoing research projects in their host labs and were thus directly involved in the planning, design, and implementation of research. This interactive science learning served as a model for teachers on how to structure their science teaching, and on how to teach their students not just procedural knowledge of scientific research, but also to think like a scientist. Rori, a beginner teacher, noted: "I'm still trying to get that experience and trying to get fun things and hands-on things and just more experience for me to help my students." Jay, another participant, believed it was an "...opportunity to learn more about the field and have something to take back to my students."

The idea of helping disadvantaged students was also evident in some responses. Kori, one of the program participants, noted that she particularly wanted to bring back her experiences to students who especially "would not have had experience or gotten the opportunity to experience those things based on their backgrounds." Gabi, another teacher, also voiced that her motivation to participate in the program was that it was "offered to Title I teachers in Title I schools."

Acquiring Resources for Classrooms

In addition to bringing new specialized science knowledge into the classroom and improving the curriculum with environmental health research science, it was also important for teachers to *acquire relevant instructional resources* for their teaching. Given that teachers participating in the current study worked in schools with a large number of economically disadvantaged students, and their school resources in science teaching were scarce, the additional instructional resources were a great motivator for their PD program participation. Pat, one of the study participants, revealed that: "I also liked the fact that it was going to be an opportunity for me to secure supplies to my classroom, for my kids."

Particular Motivators Related to Psychological Needs

Our second research question examined *specific motivators that supported teachers' psychological needs* as related to their autonomy, sense of competence, and relatedness. Teachers' testimonies in their focus groups and individual interviews illuminated strong themes of psychological needs. Using the SDT (Deci & Ryan, 2000) as a lens to examine the data, the findings provided a deeper understanding of teacher motivation supported by specific psychological needs. The themes were subsumed into three categories, in line with psychological needs described by the Self-Determination Theory, namely: *Autonomy*, *Competence*, and *Relatedness.*

Autonomy

In the current study's findings, the concept of *autonomy* refers to the importance that participants place on being the originator of their decisions and experiencing congruence between their social context and their values, interests, and needs (Richardson et al., 2014). Evidence of congruence was seen in teachers' personal interests and in their knowledge acquisition and use, which emerged as the following subthemes.

Personal Interests. Study findings revealed that teachers expressed a sense of personal interest and enjoyment in science and learning. Their decision to engage in the PD program was tied to the

intrinsic value placed on their participation. Pat's interest in new experiences motivated her decision to participate. She shared: "I love science, and I love learning, so I was eager because I knew it will put me in an environment that I'm not accustomed to being in anymore." Rori, another participant, shared about her personal interest in engaging with the PD, explaining that: "I was really interested in the research part of it. I hadn't done the research since I was in college... and so I was really excited to get back in the lab. I'm just learning about what's going on in science now."

Dylan's decision to participate in the program originated from her personal interests in addressing achievement gaps as a teacher. She voiced:

> The program talked about trying to help students who are low performing, and so I was looking for a way to close the achievement gaps in those areas, and if I can recall, yeah, that was an area of concern for me. I do have issues with certain students [with] different demographics...they just have a hard time with science.

These examples provide evidence that though each participant's individual interests were different from one another, it was a shared experience that their personal interests drew them, at least in part, to the program.

Knowledge Acquisition and Use. Participants spoke about acquiring new knowledge and experiences. Each individual participant used this knowledge and experience in different ways in their personal and professional lives. Some participants provided insight into how this experience directly applied to their curriculum. Gabi shared that "[The content] directly tied into parts of my forensic science class…. and also directly tied into my anatomy class."

Furthermore, participants spoke about making connections between their immersive lab experiences, their prior experiences in science, and their current experiences in the classroom. These statements reflected congruence between their PD involvement and personal experiences as well as their needs. Making connections with her research findings and her prior knowledge was considered most valuable for Gabi. She shared:

> The research has only helped to solidify what I have been reading before. I had firsthand experience, and I can truly say to anyone that flavonoids do help to reduce cancer and impact cancer in a positive way. And here is the proof. I had my research to prove it.

Participants experienced autonomy through personal interest and knowledge acquisition and use. A feature of the current PD program is that there were no prescribed takeaways or lesson plans that had to be used in the classroom. This flexibility allowed participants to be the originators of their decisions on almost every occasion within the program. Participants expressed the need to feel that they were in control of their experiences within this PD.

Competence

In our findings, the concept of *competence* is presented as the importance of being challenged, feeling capable of being effective, and contributing to a meaningful cause. Related to the theme of *Competence,* data analysis revealed three subthemes that emerged from the teachers' statements and are described below: Meaningful Teaching Practice, Perceived Professional Value, and Pride.

Meaningful Teaching Practice. In the current study, meaningful teaching practice refers to a science teacher who is able to provide meaningful teaching to their students and meets a personal need to feel effective in their work. Kori's reflection about her classroom practices provides evidence that it is invaluable to her that her teaching practices are meaningful. She says about her teaching:

> Sometimes, as I stand at the front of my classroom, I feel that my students have just come to school to watch me do all of the work. This is a systemic problem that needs uprooted from the bottom up; however, I am hopeful that at least within my classroom, my students will

> develop the skills to become better learners, to think for themselves, and not necessarily wait on me for the answers. That they will find initiative to look for the answers themselves.

Rori's need to engage students meaningfully was expressed in her desire to present real-life connections in her instruction. She voiced: "The lessons I teach in environmental science have only been concepts until now. I want to be able to apply my research and training here to my classroom and provide real-life examples of the information I teach."

Perceived Professional Value. In addition to meaningful teaching practices, analysis showed that participants needed a sense that their professional experiences were valued by others, such as peers and school leaders. Teachers' statements suggested that they appreciate when their professional capabilities are valued; thus, it was important for teachers to feel that their contributions were recognized within their professional spaces. This was observed within both the PD program and within their school communities. In one focus group session, the teachers spoke about their experiences with mentor scientists and doctoral students in their host science labs. Being challenged to demonstrate their capabilities was important to them. Pat, one of the teachers, articulated:

> We've had some moments where I've been able to just kind of step up and show her so she [n.r. science mentor] can see that I am capable…she'll catch herself now and say, "Oh, I'm doing it, you do it, here."

Pat's reflection shows that it was important to her that her mentor scientist saw her value in the lab as well as capable of doing the work required within the lab setting. In her explanation of her school's response to her PD participation, Gabi further demonstrates the need for perceived professional value, as she explained: "The PD program made an impact in my professional life; the school administration is actually more interested than I thought they would be. Some of them are really excited that I actually did the research." This is particularly notable because in her earlier interviews, Gabi expressed the belief that her administration likely would not notice that she did this professional development. Meaningful teacher practice and perceived professional value worked in congruence with a sense of pride to create the overall experience of competence in this study.

Pride. Pride is demonstrated in the participants' desire to feel a sense of accomplishment in their work. This refers to a feeling of satisfaction with their achievements, and it communicates that they feel capable of being effective. Pride is evident when Gabi spoke about how the program impacted her:

> I think the program has strengthened me in that I have something I can point to, to show my students the value of research and the value of their education. My students have been very impressed with what I have done…having that current research and being able to point to that poster. [My students] listened to everything I say, and they believe everything I say, and they're excited about it.

Having physical evidence of her work in the poster was a symbolic representation of her accomplishments for both Gabi and her students. Meaningful teaching practices, perceived professional value, and pride were the sub-themes that worked together to form the overarching theme of competence in this study. Competence is only one piece of the overall puzzle that underlies teachers' motivation to enhance students' science learning experiences.

Relatedness

In the current study's findings, the concept of *relatedness* encompassed feelings of belongingness and connectedness with others. Teachers' responses reflected the importance of positive, helpful relationships in their professional spaces. Participation in the PD program allowed teachers to form networks with their peers, the host lab team members, and their mentors, thereby helping them fulfil their need for belonging. Two distinct sub-themes were identified in teachers' statements. These were

supportive relationships in their PD program and supportive relationships at school with their colleagues.

Supportive Relationships in the PD Program. With reference to their host labs and mentor scientists, teachers commented on the bonds that they formed with their lab mates as a valuable part of the PD program. Jay, one of the study participants shared: "For me the relationships that I've [formed] with people here, other interns, mentors, I mean that is stuff that nobody can ever take away from me." Rori, another participant, discussed the mentorship support in the lab that was helpful to her to think about her work at school:

> Every Thursday me and my mentor got together and talked about ways we could redo these experiments or mimic these experiments on a smaller scale and on a less expensive scale, so we had those open conversations where I was like look, this is what I have in my class. I have desks, and I have one sink that works out of 8, so what can we do?

Supportive Relationships at School. Regarding the school setting, in their individual interviews, post-PD program attendance, the teachers remarked on acts of kindness or affirmations extended to them, especially from administration. Dylan, one of the teachers, noted, "…well, my school is pretty supportive of me. I'm a new teacher, but my principal was pretty nice to me." Teachers' responses also suggested that they need their efforts to be affirmed. This was most clear in Gabi's responses in one of the focus group sessions versus her individual interview. In the focus group session, which occurred in the last week of the PD program, teachers were asked about the support they foresee receiving from administration upon their return to the classroom. Gabi shared the following:

> I think for me, I can show my principal, and for that moment, while I'm talking to her, it'll be important, but once I walk away, it won't be important anymore. I'm being serious. It will only be important to me and my students, and a handful of the parents. And since I'm not one of the chosen ones, it won't be looked at as important.

In her individual follow-up interview, four months after the program, there appeared to be a shift in her perception of support from administration. In her individual interview, four months after the PD completion, Gabi voiced: "[The program] has made an impact in my professional life; the school administration is actually more interested than I thought they would be. Some of them are really excited that I actually did the research."

Experiences of supportive relationships within the PD program and within their school were important to teachers' experiences of relatedness. Teachers' experiences in the PD prepared them to position themselves as a natural conduit for inquiry-based science learning. The PD experience met key psychological needs, which, in turn, motivated them to shift the way they teach science so that students' science learning experiences are richer and more meaningful.

Discussion

Overall, the study's findings suggest that an immersive, structured mentoring program can provide teachers with authentic STEM research opportunities that have the potential to positively change their science teaching and, consequently, motivate their students for academic and STEM learning, in particular. Given the fact that the immersive STEM program presented in the current study has a long duration (i.e., 8 weeks), it allows for deeper learning and understanding of the science content and research. A strong body of knowledge and skills represents the foundation for meaningful learning, motivation, and satisfaction. This allows for better connections that teachers make regarding their science curriculum and providing students with application and inquiry-based activities that mimic teachers' experiences in the lab. Science educators play a crucial role in providing their students with strong, specialized knowledge and skills; well-equipped teachers can facilitate authentic and engaging

experiences with STEM content (Weng et al., 2022). To bridge the gap between current science standards and science teachers' content knowledge and experience, rigorous and well-planned professional development is required (Thomson & Gregory, 2013). This aligns with research showing that teachers are more motivated to participate in and sustain engagement with PD when it provides relevant, content-rich experiences and clear opportunities for classroom transfer (Guskey, 2003; Hubbard et al., 2022, 2024).

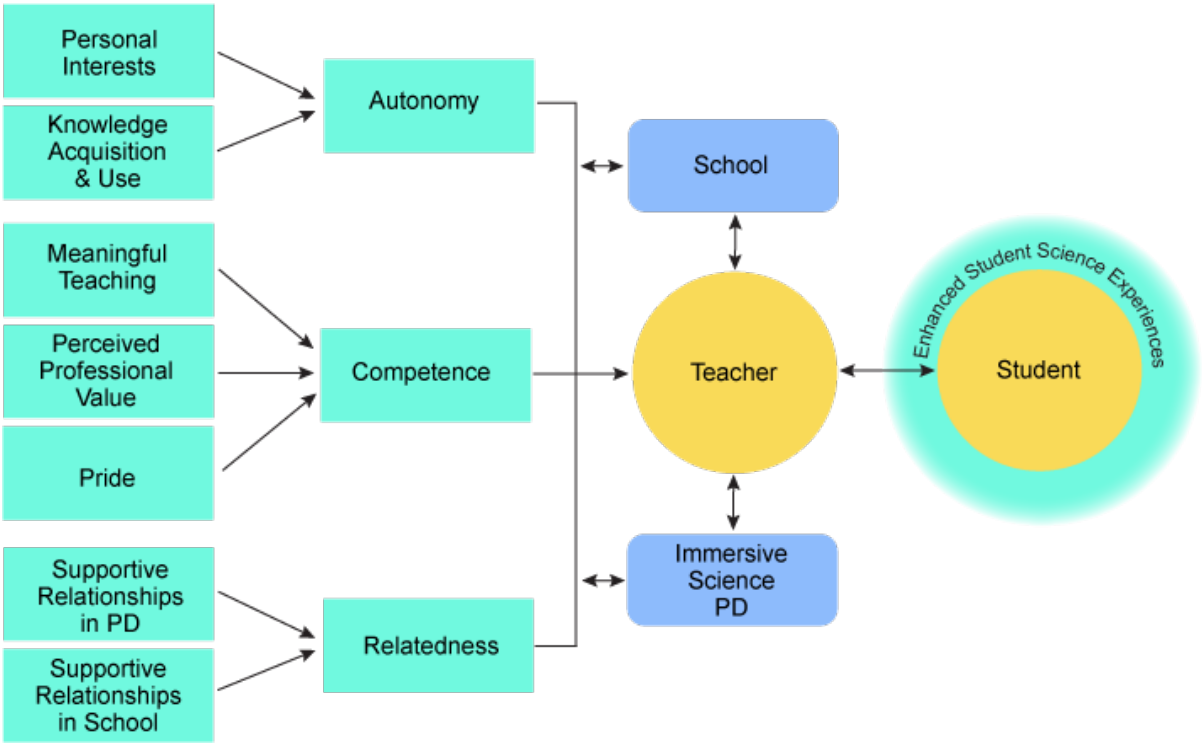
Furthermore, the current study shows that science teachers' psychological needs are at the forefront of their motivation to participate in such PD programs. Study findings generally suggest that the teachers' decision to voluntarily participate in the science PD program was hinged on their desire to enhance their students' science learning experiences. Underlying their motivation to participate were each participant's psychological needs of competence, autonomy, and relatedness.

The design of the PD program allowed for teachers to enhance their own science learning experiences and then transfer that experience to their students. Participants' voices illuminated their emphasis on experiences that support their need for autonomy, competence, or relatedness. This held true whether teachers shared details regarding the context of the school or the PD program.

Although these are in three specific categories, they appear to flow seamlessly across categories and integrate in a complex system (see Figure 2). This finding is supported by other research that recognizes teacher motivation in a more fluid, global approach (Garon-Carrier et al., 2015; Jesus & Lens, 2005). The PD program outlined in this study offered participants autonomy through the opportunity to seek personal interests and the freedom to use the knowledge they acquired in their own unique ways. Competence was another psychological need addressed by teachers in this study. Participants felt a sense of competence when they were able to offer meaningful teaching practices that allowed their own experiences and knowledge to guide instruction over scripted curriculum. The most compelling finding was related to participants' relatedness. Participants experienced supportive relationships both within the context of the PD program and within their schools. This opportunity to create meaningful relationships met the participants' psychological need of relatedness. These patterns reflect established findings that teachers' willingness to engage in PD and implement new practices is strengthened when PD supports their autonomy (Davis & Wilson, 2000; Gorozidis & Papaioannou, 2014), nurtures their competence (Jang, 2008; Reeve & Jang, 2006), and provides relational support from peers and mentors (Thomson & Turner, 2019). Teachers feel driven to enhance their students' learning experiences when they feel capable of doing so, when they have an input in the experience, and when they are supported and recognized by others (Korpershoek et al., 2020). Similar research suggests that teachers' experiences that are based on supporting their learning needs, such as autonomy, relatedness, and competence, can be transferred to classroom teaching, in addition to their newly acquired specialized knowledge and skills, thus making a significant contribution to enhancing student learning and intrinsic motivation (Chiu, 2024; Thomson, 2024).

The findings help clarify the nature of motivation in science teachers. Although the interview protocol only asked one question about motivation as it relates to attending the PD program, greater insights about motivation were seen throughout the interviews and focus group discussions. A key finding was in Gabi's response about support from administration. Gabi's initial reports of not being "important" in her school were transformed to reports of school administration being "more interested" in her. These statements speak to a shift in Gabi's perspective about her worth in that professional space. It also speaks to the factors that were important to her. Although these statements are connected to relatedness, they feed into feelings of competence. One may question how these external factors, such as affirmation, may lead to intrinsic motivation. Ryan and Deci (2000) explained that internalization and integration are central to this process. Internalization refers to taking in a value or regulation, whereas integration speaks to transforming a value or regulation into one's own (Ryan & Deci 2000).

Figure 2. *Network Model of Teacher Motivation and Impact on Students (Current Study Findings)*



Limitations and Future Research

Data used in the current study were previously approved for use by IRB. A potential limitation would be the fact that participants were paid a stipend for their participation in the NIH funded program and were provided with gift certificates upon the completion of their individual interviews (which was after the PD program, during the teacher's academic year). Although the study's findings clearly illustrate that the motivation for program attendance was intrinsic, the extrinsic motivation (e.g., stipends for participants and free instructional resources) likely provided additional motivational support for teachers. In the current study, the number of participants ($N = 8$) is appropriate, given the case-study qualitative research design, which aims at describing participants' overall PD experiences and analyzing individual differences in how motivation is experienced and expressed (Kennedy, 2016). However, future research can investigate larger groups of participants with a mixed-methods design to explain quantitatively the longitudinal growth or trends in participants' motivations, augmented by qualitative data capturing a range of experiences among participants. Further, future research can compare and analyze the different types of PD programs in which specific contextual factors can be modified to enhance one or more components of the SDT, such as participants' need for competence, autonomy, and relatedness.

Implications

Study findings provide a starting point for further research on teacher motivation as it relates to professional development and teachers navigating their professional spaces. It presents a more detailed picture of motivation, uncovering areas of importance for teachers as reflected in their accounts of their experiences. The current study has implications for professional development program design, as it provides key input from teachers that can be used to modify existing programs to meet the needs of teachers who subscribe to them. The findings can also be used to educate

teachers and administrators on factors that would be effective in building teachers' intrinsic motivation in their practice.

Additionally, programs like this benefit the teachers as much as the students. With rapid advancements in the global economic and technological climate, there is a growing need for a qualified STEM workforce, along with a call to diversify STEM careers (Chiu, 2024). Effective mentoring of STEM programs is crucial for teachers so they can provide the highest-quality education for all students, particularly those working with underrepresented populations who have difficulty identifying with STEM careers (NSF, 2027).

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Appendix A

Sample Items from Focus Group Interview Protocol

Q: You are in the second week of the program. Talk a little bit about your experiences so far. What sort of experiences have you had in the lab—good, positive, negative? Give some examples. Let's give everyone a chance to talk about that.

Q: What you're doing, we're not going to have such extensive presentation of each one of you, but I just want to ask if some of you want to touch on what was valuable in the lab and your experience. What did you find valuable, and what was challenging? So just out of your head, if you can think of two things we found valuable and two that were challenging just throw out things.

Q: Please share about your teaching confidence teaching environmental health science topics.

Q: Do you think you can be a scientist? Do you think your students can be scientists—at least one day? Think about the students that you teach.

Q: Talk a little bit about what was your initial motivation to come to this program (to this professional development)? And now that you've been here for two weeks, how relevant do you think this is to your teaching experience to take back to the classroom?

Q: How relevant is this experience taking back to your teaching? Do you think the time you had here is relevant for your teaching?

Appendix B

Sample Items from the Individual Interview Protocol

"Hello (participant name). Thank you for agreeing to participate in this interview which, will last approximately 20–30 minutes. I, (researcher's name) will conduct this interview. If you are ready, we'll start with our first question.

1. Please tell me a little bit about yourself, about your teaching experience (Probe: i.e., subject taught, grade level, etc.).
2. How long have you been in teaching?
3. If you no longer teach, do you work in an education-related area? Please give specific details.
4. You are one of the PD participants in the program this past summer (____) . How did you find out about this program?
5. What **motivated** you to participate (engage) in the program?
6. Can you talk a little bit about what kind of **expectations** you had going into the summer program? Were these expectations met?
7. Describe a little bit your **science teaching efficacy:**
    a. *before* and *after* your PD program.
    b. at the present time: How confident are **you now** about your science teaching related to the EHS topic?
8. What do you consider **to be the most valuable** about your participation in the program?
9. In what ways the program experiences can make (or made) an impact in your **professional, social or personal life**? What about your students?
10. The following questions ask you about your **PD involvement before & after** attending the program:
    a. What types of PD activities did you have *befor*e attending the program?
    b. What types of PD activities did you have *after* attending the program?
    c. What other *activities* (or PD related) did you have since attending the program and who provided these *opportunities* for you?
11. Can you talk a little bit about your **emotions** *before* and *after* your summer PD program?
12. Please describe what **changes in your teaching practices** you made after attending the program and **how the program provided the impetus for you** to make these changes. (Probe: If you are not in the classroom consider any changes you made to your teaching philosophy after attending the program).
13. In what ways do your school and district **provide support for you to implement in your teaching** the knowledge and skills you gained from attending the program?
14. In what ways do your school and district **provide support for you to share with others** (i.e., colleagues) the knowledge and skills you gained from attending the program?
15. Do you see yourself working as a scientist one day?
    a. Do you think **you can be a scientist/ or have a career in science**? (Probe: Why is that?)

   b. Do you see your students working as a scientist one day? Do you think they **can become scientists / or have a career in science?** (Probe: Why is that?)

16. How would you characterize overall, your PD experiences?
17. What challenges did you/have you overcome, whether *personal, social or economic,* during your professional development, either this summer or in other PD opportunities?
18. Do you, or have you ever, felt that being a member of a minority group has affected your opportunities for professional development or professional growth? Probe: If yes, please explain (or provide an example).
19. If there is anything else about your **professional or academic involvement related to, or as a result of your summer PD program participation**, please feel free to mention (and provide details). Please feel free to make **any additional comments regarding** your program experience, or feel free to elaborate on something if you didn't have the chance to do so.

Thank you for your interview participation and your great feedback!

Appendix C

Sample Coding

Code	Definition	Inclusion criteria	Exclusion criteria	Example
Length of time in School County	Any evidence highlighting number of years, months, weeks, days employed with School County	Evidence highlights number of years employed as a teacher in School County	When evidence refers to positions other than teaching duties in School County or where positions held outside of School County	*This is my going on my second year, so have not been in* School County *long enough*
Length of time teaching science	Any evidence highlighting number of years altogether teaching science	Evidence highlights total number of years teaching science	Evidence refers to teaching experiences in other subject areas.	*I've been teaching science for going on 18 years.*
Love for science	Any evidence referring to love, passion or personal interest in science research, or studies	Any expression of love, passion or personal interest in science research or studies	When evidence refers to love for teaching	*I've taught physical science, earth science, ap biology and um like I said my main area is biology, but I love science.* *I liked the research part.* *I'm looking forward to that and the lab part, the research department.*
Information given by superiors	Any evidence suggesting that information was disseminated by a person in a higher level of office	Evidence suggests that information was given to the interviewee by a supervisor, or someone in higher authority	When evidence refers to information shared by colleagues at the same level on an org chart.	*So my principal sent out an email to everybody in this school, um, and I think the department chair sent out another one, so that's how I found out about it.*
Improving practice	Any evidence that describes a desire to improve teaching practice.	When evidence refers to actions or thought processes about improving teaching skills		*I tried to find something in the summer that will also help with my curriculum* *let them do more, said being more intentional with the students being more in control of the class*
Helping disadvantaged students	Any evidence that speaks to helping students in disadvantaged positions	Evidence suggests helping students who are weaker, low SES, minority, etc.	Improving practice	*help students who are low performing and so I was looking for a way to close the achievement gaps in those areas* *So, I was looking for ways to, to teach science and make it more interesting to them so that they'll be excited about science* *I looked around and I didn't see a lot of females and a lot of minorities*

Pride in one's work	Any evidence suggesting satisfaction in oneself and one's work	Evidence that shows satisfaction with ones' work	Does not include group pride	
Changes to teaching philosophy	Evidence suggesting a change in the way one thinks about teaching, or the purpose of teaching	Any evidence suggesting a positive change to how one approaches teaching conceptually.	Does not reflect actual changes to one's practice	*If we wanted to be lifelong learners, we have to teach differently instead of like teaching just for the test to be, you know, if we want them to have to have a career in STEM, would have to want them to have an interest in it, not just for the test.* *My level of patience, I have to use it when they asked me maybe the same question over and over. I have to be willing to, um, explain it a number of times.*
Positive communication with others	Any evidence that highlights relating with others.	Any evidence that describes placing value on talking to or relating with others	Does not include communicating for everyday needs.	*I guess, I mean for me, I learned that research, was not really for me, um, is too quiet being in the lab I miss the, the Ms. so and so and so and so. I liked that the communicating with the kids* *I talk to fellow coworkers about a shared with my children, of course with my students. Um, my principal. So, I talked to a, shared my experience with other people.*
Feelings about new experiences	Any evidence that speaks to emotions surrounding novel experiences	Speaks specifically to experience of new experiences		*I was excited because, um, it was something different. I hadn't done research since Undergrad to be honest.*
Supportive relationships	Any evidence suggesting that teachers experience support from relationships in science	Descriptions of relationships from school or in the field/lab	When evidence refers to family relationships	*Um, well my school is, is pretty supportive of me. Um, most of the time if I ask her something, I'll get it. I, with the budget cuts, my class sizes have increased, and it may be just because I'm a new teacher, but my principal was pretty, pretty, pretty nice to me. That's good.*
Expectations of students	Any evidence suggesting that teacher has an expectation of her students	Use of words that suggest expectations	Evidence refers to expectations of school, parents, or system in general	*I'm definitely and there's so many things that they can do in the area of science so they can definitely do this.*