

From Industry to Classroom: The Benefits of Combining STEM Industry Immersion with Pedagogical PD

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Abstract

STEM experiences for teachers (SETs) are promoted to enhance students' STEM learning by immersing educators in industry settings. The SET professional development (PD) model assumes that deep immersion alone motivates pedagogical change. However, these initiatives often lack the pedagogical PD necessary for translating industry experiences into classroom practices. This study explores the effectiveness of The Fellowship Program (TFP, pseudonym). TFP is a year-long program that combines a three week SET with 80 hours of pedagogical and leadership development (SET+PD). This qualitative study used Clarke and Hollingsworth's Interconnected Model of Professional Growth (IMPG) to analyze the impact of TFP on 32 teachers' professional growth. Our findings reveal that participants identified Industry Connections and Professional Development as particularly impactful elements of TFP. TFP's SET+PD model strongly influenced educators' Personal Domain, including their knowledge, attitudes, and beliefs. There was a consistent pathway from changes in teachers' Personal Domain, through their Domain of Practice, to positive outcomes in their Domain of Consequence (e.g., increased student opportunities and enhanced teacher leadership). This study underscores the efficacy of the SET+PD model for sustainable STEM integration in classrooms; highlighting the need for PD programs that improve teachers' STEM knowledge, pedagogy, self-efficacy, and network.

For decades, there have been consistent calls to improve teachers' practice through professional development (PD) and to enhance teachers' understandings of both scientific research and STEM industries through STEM immersion experiences (Blanchard & Sampson, 2017; Hurley et al., 2024; Margot & Kettler, 2019; Sims et al., 2023). The ultimate goal of these initiatives is to improve student learning and prepare students for future careers (Hurley et al., 2024; Margot & Kettler, 2019). Much research has been devoted to identifying PD best practices, developing models for effective teacher pedagogical PD, and examining the effects of various PD models on teacher professional growth (Clarke & Hollingsworth, 2002; Kennedy, 2016; Sims et al., 2023). Concurrently, significant funding has been allocated to creating STEM industry experiences for teachers (SETs; Bowen & Shume, 2018; Marqusee, 2023). Notably, these lines of work rarely intersect. The few extant SET programs provide immersions, but not pedagogical PD (Hurley et al., 2024). Further, Hurley and colleagues (2024) note in their meta-analysis of literature on SETs, very little research has focused on evaluating the impacts of these programs on teachers' professional growth. Achieving a shift in in-service teachers' daily practice towards ongoing authentic, STEM learning experiences that prepare students for future work cannot be accomplished through either pedagogical PD or SETs alone. Rather, in-service teachers must be provided with SETs paired with research-based pedagogical PD (SET+PD) that equips them to leverage the knowledge acquired during an SET. While Hurley et al. (2024) identified two established SET programs, we were unable to identify any SET+PD programs in the literature. Recognizing the critical need for detailed descriptions and research on the SET+PD model, this study offers an initial examination of The Fellows Program (TFP, Pseudonym). TFP addresses the necessity for authentic SET experiences for in-service teachers, coupled with research-based pedagogical PD that enhances teachers' leadership skills and equips them to create genuine learning experiences for their students. Consistent with PD goals of teacher development that leads to student outcomes, this study was guided by the following research questions: (1) What elements of TFP do participants identify as beneficial? and (2) How does TFP influence the professional growth and practice of in-service teachers?

Theoretical Background

STEM Immersion Experiences and Effective Professional Development: The primary objective of PD programs for in-service teachers is to enhance their practice to improve student learning and career prospects. Most SET programs assume that immersing teachers in STEM environments will equip them with the knowledge and motivation to bring authentic STEM experiences to their students (Hurley et al., 2024). Hurley et al.'s (2024) meta-analysis identified only two established and studied programs that provide SETs to in-service teachers: Georgia's GIFT Program and North Dakota's Educators in Industry: K-12 Externships. Research on these programs shows they successfully increased participants' knowledge of STEM careers and workforce skills, as well as their intentions and motivations to incorporate lessons from their externships into their classrooms (Barrett & Usselman, 2006; Bowen & Shume, 2018; 2020). However, Sims et al.'s (2023) recent meta-analysis of teacher PD literature notes that increasing teachers' content knowledge and motivation alone is insufficient for lasting pedagogical change. They argue that for PD to meaningfully improve student learning outcomes, it must instill insights (I), motivate change (C), develop techniques (T), and embed these changes in practice (P). Evaluating STEM immersion programs against Sims et al.'s (2023) framework suggests these programs likely provide insights and motivate change but lack in developing techniques and embedding new knowledge in teachers' practice. Therefore, we propose that sustainable,

authentic integration of STEM industry learnings in classrooms requires PD models that combine SETs with pedagogical and leadership training. This study examines the impact of TFP's SET+PD model on teacher growth.

Interconnected Model of Professional Growth: Understanding the actual effects of this SET+PD model on teachers' professional growth can be accomplished through the lens of the Interconnected Model of Professional Growth (IMPG; Clarke & Hollingsworth, 2002). The IMPG describes the complex nature of teachers' professional growth. Clarke & Hollingsworth's (2002) model divides teachers' experiences into five domains: External Domain, Personal Domain, Domain of Practice, and Domain of Consequence. These domains are all situated within the External Domain (i.e., teachers' instructional context). According to Clarke and Hollingsworth (2002), teacher professional growth begins with experiences, usually PD engagements, that comprise the External Domain. The External Domain acts as an input that influences teachers' Personal Domain (i.e., their Knowledge, Beliefs, Attitudes, Dispositions) and their Domain of Practice (i.e., their instructional practice). Ultimately, the results of their experimentation in the Domain of Practice emerge in the Domain of Consequence as salient outcomes. Importantly, Clarke and Hollingsworth (2002) emphasize that teachers' professional growth does not occur in an isolated domain or in a linear fashion, rather professional growth is the result of ongoing cycles of reflection and enactment that connect the various domains as teachers learn, experiment, gather data, reflect, and revise.

Methods

This qualitative study included the experiences of 32 in-service teachers who participated in TFP between 2018 and 2021. Twenty-five of the 32 interviewees provided grade level and subject area data. Fifteen of the teachers taught middle or high school, with the remainder being elementary level teachers and one community college instructor. The number of fellows per subject area were: 27 STEM instructors, 6 career and technical education instructors, 15 humanities instructors, and 4 "Other" instructors. Note, many Fellows reported teaching multiple subject areas.

Context: TFP's structure is rooted in situated learning theory whereby learners gain new skills through authentic participation in contexts outside of their daily experience (Lave & Wenger, 1991). The Fellowship year includes: a competitive selection process; a three-week SET; development of a strong community of practice (Mercieca, 2017); 80 hours of research-based PD focused on innovative pedagogies (Darling-Hammond *et al.*, 2017; Desimone, 2009; Kennedy, 2016), inclusive classroom culture (Frank, 2018); teacher leadership (Nguyen *et al.*, 2020); and implementation by role model classroom teachers (Darling-Hammond *et al.*, 2017). Across their Fellowship year, participants also create a product that translates their immersion learnings into experiences for their students.

Data Collection: We report the findings of our qualitative analysis of 32 interview transcripts. These transcripts represent a portion of a larger data set ($N = 60$) of evaluation interviews and focus groups conducted between 2018 and 2024. Data utilized in this study was initially collected as a component of TFP's annual program evaluation. Interviews with Fellows were conducted by third-party evaluators via phone and Zoom. Interviews followed a semi-structured protocol, with major topics covering Fellows' experiences with (1) changes to themselves or

their practice, (2) network building, (3) their three-week SET, and (4) their overall feedback about their time in TFP.

Data Analysis: Our qualitative data analysis was conducted using Atlas.ti (version 24.1.1) and employed both inductive and deductive approaches. First, an initial set of eight interviews (two from each year 2018-2021) were open-coded (Corbin & Strauss, 2015) by three of the authors to identify initial codes and themes. Double-coding was often employed to illuminate related concepts when respondents referenced multiple ideas in a single train of thought (Saldana, 2009). The authors then discussed discrepancies between their analyses until consensus was reached on an initial set of fifty-eight codes. This process was repeated through two more rounds, resulting in twenty-four documents receiving coding from three coders and a final codebook consisting of 46 codes. Ten percent of the data was then selected to be separately coded by the first and second authors. Atlas.ti was used to calculate an intercoder agreement of 75.4%. The final 46 codes were then grouped into 13 emergent categories, and the 13 emergent categories were deductively grouped under the main elements of Clark and Hollingsworth's (IMPG (i.e., Change Environment, External Domain, Personal Domain, Domain of Practice, Domain of Consequence, Reflection and Enactment). Finally, the lead author coded a further eight transcripts, and an analysis of both transcript content, code frequencies, and code co-occurrences was conducted. Four hundred eighty-nine quotations were included in our analysis. Note, the coding hierarchy is identified as follows in the report of results: IMPG Domain, Emergent Category, Code.

Results

Impactful Elements of The Fellowship Program: Though participants were not directly asked to name program components that they found to be particularly beneficial, the most frequently used codes ($n = 319$) in this analysis pertained to the External Domain (i.e., impactful elements of the Fellowship program). Within this domain, the most frequently used categories of codes were Industry Connections ($n = 151$), Professional Development ($n = 92$), and Program Infrastructure and Values ($n = 58$). The following quote by a 2019 Fellow captures sentiments expressed by many of the interviewees:

What they did really, really, really, really well is value educators. They value educators with time. They value educators with money. They value educators with [industry] network. They value educators with more than just a little pat on the back. They give them meaningful experiences.

Impact of Fellowships on Teachers' Professional Growth: While teachers referenced changes to each of their IMPG domains, it appears that their Personal Domain was most affected. Teachers referenced changes in their Personal Domain most frequently ($n = 212$), followed by the Domain of Consequence ($n = 126$) and the Domain of Practice ($n = 122$). Within the Personal Domain, teachers most frequently spoke of changes in their Knowledge ($n = 83$) and Beliefs ($n = 79$); especially, *Feelings of Increased Self-Efficacy* ($n = 66$). This shift is reflected in the following quotation from a 2018 Fellow, “[The Fellowship] boosted my confidence, I feel like a better teacher, I feel like a more effective teacher and I feel like I’m more inclined to reach out within my school as a teacher/leader.”

In the Domain of Practice, teachers most frequently referenced shifts in their Pedagogy ($n = 79$), specifically *Integrating Specific Learnings from their Immersion* ($n = 30$) and shifts

towards *Student Centered Teaching and Learner Agency* ($n = 29$) and *Forming Community Connections* ($n = 33$). For example, a 2019 Fellow stated:

Especially with my immersion, it was all about collaboration and hands-on. So I've tried to incorporate that more in the classroom. Having students work together, having students be more hands-on with tasks, instead of just sitting there and just taking notes and reading from a book, giving them that experience that they can actually take what they've learned and put it into practice.

Regarding teachers' Domain of Consequence ($n = 126$), 95 quotations were attached to specific *Teacher Outcomes*, while 31 quotations were associated with specific *Student Outcomes*. Under *Teacher Outcomes*, participants most frequently spoke of instances coded as *Created Opportunities for Students* ($n = 54$) and *Teacher Demonstrated Leadership* ($n = 28$). Providing a concrete example of how their time as a Fellow helped them create opportunities for their students, a 2020 Fellow remarked that:

[During The Fellowship] I asked a faculty member if he could come and do a workshop at our school ... he reaches out into really rural, high poverty, communities, and schools with these do-it-yourself microscopes. He came out and did a workshop. Brought all the materials for our school and each teacher built one of these microscopes to have in their classroom. Now we use those in clubs each month.

Frequently, opportunities like these created by teachers were associated with the specific *Student Outcome* of *Increased Student Engagement* ($n = 27$). As illustrated in the following quote from a 2020 Fellow, "the kids were just way more engaged and it was so hands-on and I actually noticed that some kids that, you know, came to perform or be a little lower academically, were thinking...or showing me that they were thinking about science in a more openly curious way."

Interaction between Individual Domains: When considering the frequency of code co-occurrences that provide evidence of teachers discussing interactions between domains, two major patterns became clear. First, there were strong interactions between teachers' Domain of Practice and their Personal Domain with 43% ($n = 52$) of all Domain of Practice codes attached to a quotation that also has an associated code for Personal Domain. More specifically, changes to teachers' *Knowledge* (Personal Domain) through *New Instructional Practices* were often connected to discussions of changes in teaching practice (Domain of Practice) through shifts to *Student Centered Teaching* and *Real-world Instruction*, and new focuses on *Classroom Culture*. As noted by a 2019 Fellow:

I think my instructional practice has really done a 180. Honestly, it's gone from mostly scripted lesson plans that focused down on one or two goals that we just gotta do, to more of an inquiry-based type practice ... I think the kids are really responding. My lessons are more interdisciplinary. I've been able to incorporate science and engineering and just make connections in those fields, as well.

Second, the most salient pathways of interaction in this analysis involved co-occurrences of *Increases in Feelings of Self-Efficacy* (Personal Domain) with enactment through teachers taking a specific *Agentive Action to Form Community Connections* (Domain of Practice), *Create Opportunities for Students* (Domain of Consequence), or *Demonstrate Leadership* (Domain of Consequence). The following quote from a 2019 Fellow is characteristic of the sentiments of many interviewees:

I think a big thing for me is realizing that I can't do this alone. Then understanding that there are people that do want to help you. What it has done for me is made me more bold

in just asking for the things that I need as a teacher. Those aren't always like consumables or things that come with money, it's going to businesses or even partnering with [University] this year and saying like hey, we need mentors from your program, and people actually saying yes. So it's made me realize there are people out there who do want to also affect education, and it takes teachers who are brave enough to hear no a couple of times and keep going.

Discussion

As noted by Hurley and Colleagues (2024), there are very few programs focusing on developing in-service teachers' practice through STEM immersion experiences, and the known programs focus primarily on STEM immersion but not intentional pedagogical development. The handful of studies on these two programs indicate that they increased teachers' knowledge of STEM career skills and pathways, changed their perceptions of important workforce skills, enhanced their confidence to bring STEM experiences to their students, and resulted in real-world lessons for their students (Barrett & Usselman, 2006; Bowen & Shume, 2018; 2020). These studies, however, did not probe how the STEM immersions impacted teacher professional growth and only made cursory references to actual changes in classroom practice. Our work builds upon these studies by highlighting the effects of TFP's SET+PD model on teacher professional growth and practice. The results of this study (1) show that participants viewed both industry immersion and PD as impactful elements of TFP; (2) reveal that TFP's model strongly affected multiple facets of educators' Personal Domain (i.e., Knowledge, Attitudes and Beliefs); and (3) highlight a consistent connection between teachers' Personal Domain, through Enactment in their Domain of Practice (e.g., Integrating Learnings from their Immersion, Forming Community Connections, and Student Centered Teaching), to salient outcomes in their Domain of Consequence (e.g., Opportunities for Students and Teacher Leadership).

The mechanism behind the reported changes in the interviewed teachers can be analyzed through the lens of teacher PD frameworks. Isolated STEM immersions provide a specific body of knowledge or new insights (Kennedy, 2016). However, Kennedy (2016) notes that PD in these categories tends to have the lowest impact on student learning, likely because it only builds teachers' knowledge without offering new pedagogical strategies or influencing beliefs, such as self-efficacy (Bandura, 1997), that could motivate the conversion of new knowledge into pedagogical action. While we lack direct evidence of improved student test scores, this study presents substantial evidence that TFP teachers made significant and sustained changes to their instructional practices, resulting in new industry-focused learning experiences for their students and enhanced student engagement. We propose that the significant changes in teachers' professional growth and practice were driven by TFP's SET+PD model, which provided experiences addressing each element of Sims et al.'s (2023) framework for effective PD. Given the findings of this study, we argue that equipping teachers to integrate authentic STEM experiences into their classrooms as a sustainable element of their daily practice requires not only enhancing their knowledge of real-world STEM settings but also building their pedagogical toolkit, enhancing their self-efficacy and ability to lead, and providing them with the skills to both build and maintain industry connections.

In conclusion, the findings of this research contribute to the existing literature on STEM experiences for teachers by highlighting the beneficial and non-beneficial characteristics of a SET+PD fellowship program and illustrating how such a program can support multiple domains of teachers' professional growth. This proposal will interest NARST members who are focused

on authentically connecting industry and basic research facilities to K-12 classrooms, in-service teacher PD, and strategies for assisting non-science educators in integrating science and other STEM disciplines into their teaching.

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