PARTNERSHIPS: A SYSTEMIC STUDY OF TWO PROFESSIONAL DEVELOPMENTS WITH UNIVERSITY FACULTY AND K-12 TEACHERS OF SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

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Abstract

While it can take different forms, science, technology, engineering, and mathematics (STEM) K-12 teacher professional development (PD) is important around the world. Though all stakeholders play critical roles in PDs, the author focuses on the larger system that supports the PDs. As such, this research study focuses on the PD results, but also on the explanation of the systemic nature of the PDs studied. Partnerships, including building of relationships, are explored in that system. In this mixed methods study of two K-12 teacher PDs (n=31 and 19 total PD days), conducted in the western United States, the author utilizes quantitative and qualitative data collection methods to reinforce quality PD practices and suggested strategies. Results indicate that 90% of the K-12 teachers were highly engaged in the STEM content and partnership building. Pre to post K-12 teacher perception scores regarding astronomy use in STEM content courses showed noteworthy improvement from 16% to 84%. Furthermore, K-12 teacher perceptions regarding creation of partnerships and collaborations rose from 26% to 90%. Other findings showcase themes of reflection, collaboration, STEM integration, and inquiry as well as a need for partnership building time. Overall, when the K-12 teachers worked together in a structured PD over an academic year (2014-2015) for a selection of 19 days (13 summer days and 6 Saturdays during the academic year) partnerships were formed and provided added organization for the PD system. Faculty/PD team communications and continuous K-12 teacher support were also critical factors for systemic PD success. Access to K-12 teacher created lesson plans that use astronomy as a vehicle for STEM lessons can be accessed free of charge at the following websites: http://physics.uwyo.edu/~mike/workshop/index.html and http://www.physics.uwyo.edu/~aschwortz/LASSI/
Key words: *teacher professional development, systemic nature, partnership, reflection, inquiry.*

Introduction

In order to empower STEM K-12 teachers to inspire future STEM experts, research must make an effort to provide current K-12 teachers with targeted professional development (PD) in both content and structure. Professional development revolves around any K-12 teacher learning, usually in a structured process, for the benefit of their students (Avalos, 2011). Science, technology, engineering, and mathematics (STEM) K-12 teacher PD is important to instructors, schools, and communities around the world, although they often take different forms. "Policy makers, school and district leaders, and researchers are all increasingly concerned with improving the quality of evidence about the effectiveness of teacher professional development, especially in terms of its impact on desired reform outcomes" (Penuel, Fishman, Yamaguchi, & Gallagher, 2007, p. 921). Thus, PDs are vital to K-12 teachers as well as K-12 student learning.

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Problem of Research

Understanding the process of the PD could improve the structure of the programs presented as well as K-12 teacher and student outcomes. Hewson (2007) states, that "… research consider not only the people involved in [science] professional development, but also the systems in which these programs are embedded" (p. 1201). Accordingly, there is a need that solicits research, not only for PD results, but also for the explanation of the systemic nature of the PD studied. Hence, researchers should explore the features of PD systems. Partnerships, including the building of relationships through discussion, should be a part of that system.

Research Focus: Theoretical Framework and Literature Review

Any system is tied to the culture of the area, and culture must be considered for PD creation. Culture has been defined as "an interactive web of meaning, whose parts are in continuous interaction with each other" (Jurasaite-Harbison & Rex, 2010, p. 268). Valuing the cultural component, the author used Vygotsky's (1978) socio-cultural theoretical framework, which hinges on situations that encourage change and thus lends itself to interactions that lead to K-12 teacher knowledge making. In order to understand the context of K-12 teacher PD via a socio-cultural framework, the author briefly explores effective PD characteristics, the systemic nature of PD, and partnerships in the following literature review.

Professional development should improve content knowledge, pedagogy, and dispositions (Burrows, Borowczak, Slater, & Haynes, 2012; Crippen, 2012; Loucks-Horsley, Love, Stiles, Mudry, & Hewson, 2003; Zozakiewicz & Rodriguez, 2007) and allow teachers to create new instructional materials (Burrows, Briener, Keiner, & Behm, 2014; Jackson & Ash, 2012; Stolk, DeJong, Bulte, & Pilot, 2011). In relation to content knowledge, practices that promote authentic scientific research (Spuck, 2014), socioscientific issues (Zeidler, 2014), and inquiry (Marshall & Alston, 2014) are preferred for crucial impact with teachers. Effective PD focuses on "curriculum-linked [sessions focusing] specifically on how to enact pedagogical strategies, use materials, and administer assessments associated with particular curricula" (Penuel et al., 2007, p. 928) as well as "multiple cycles of presentation and assimilation of, and reflection on, knowledge" (p. 929). Professional development should also concentrate on general and specific content knowledge, student objectives, and common student misconceptions (Penuel et al., 2007). PD that includes "time for instructional planning, discussion, and consideration of underlying principles of curriculum may be more effective in supporting implementation…" (Penuel et al., p. 931). Consequently, for successful PDs, faculty/team members must attend to all of these PD aspects in the PD model – or system - that they create.

A system has working and moving parts that interact with each other, and PD processes are also systemic in nature. Overall, K-12 teacher PD is embedded in the system of learning and development. The systemic nature of PD is an important consideration of PD development, and when teachers see a connection between the PD and the needs of their classroom – and the district, community, and the like - they are more likely to adopt the curricula (Penuel et al., p. 931). Two methods to engage teachers in the PD processes are school-university partnerships and K-12 teacher co-learning (Avalos, 2011). These practices supplement and reinforce learning so that K-12 teachers can translate new knowledge and revise or create curricula. The research lines that include communities of practice, communities of learning, and peer coaching speak to the value of K-12 teacher co-learning (Avalos, 2011).

Partnerships, or meaningful work with and for each other (Burrows, 2011), hold all participants accountable during and after the PD. When teachers revise or create a new curriculum with their peers, it assists in knowledge sharing with others, but it also increases the work expectations of the K-12 teacher (Avalos, 2011). The creation and implementation of new materials are linked with higher self-efficacy, or a K-12 teacher's belief that he/she has the experience and knowledge to conduct the new material (Burrows et al., 2012; Ross

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& Bruce, 2007). Conditions of high self-efficacy coupled with valued collaborative learning are the most productive PD environments (Avalos, 2011). Additionally, K-12 faculty/PD team members should value teachers in PDs as partners and they should engage in defining roles in the process (Avalos, 2011). Action research, a methodology that values social change through democratic participation, social justice, and community empowerment, is one means of encouraging stakeholder participation and partnership building (Brydon-Miller & Coghlan, 2014) while creating and implementing PDs.

Methodology of Research

General Background of Research: Gap in the Literature and Research Questions

This research study is grounded in two gaps in the literature: the first by Hewson (2007) to study the systemic nature of PDs and the second by Penuel et al. (2007) to include purposeful PD discussions. This was a mixed methods work, where quantitative and qualitative data was collected during two separate PDs. The author chose a mixed methods research agenda for two reasons: one was to use diverse methods in order to achieve data validity (triangulation) and the second was to more richly explore the perceptions of the participants. The contexts of the two PDs explored in this study were different. The first K-12 astronomy STEM integration PD, hosted 15 teachers for three days - from 8 am until 5 pm daily - during the summer 2014, and the second K-12 PD, hosted 16 teachers for 16 days – from 8 am until 5 pm daily plus night telescope work - during summer 2014 and school year 2014-2015. In this research study, the author examined the characteristics of PDs that provide system support for, not just the creation of, the implementation of curricula and how discussion influences the system and the K-12 teachers. Thus, the author concentrates on K-12 teacher satisfaction and perceptions with PD content and participant interactions, as well as faculty perceptions and interactions during two PDs over the course of one full calendar year. The research questions that guided this study include: 1) what are K-12 teacher perceptions/use regarding the PD *content* provided? 2) What are K-12 teacher perceptions regarding the PD *partnerships*, especially in relation to discussion?, and 3) What are faculty perceptions regarding the PD *partnerships* with K-12 teachers?.

Sample of Research

There were two sets of participants in the study, and both included K-12 teachers from three U.S. states participating in the PDs as well as the faculty/PD team that created and implemented the PDs. Both studies were conducted in the western United States, and the participants self-selected the professional development. The first study involved 15 K-12 teachers, and the second study involved 16 K-12 teachers. There were eight faculty/PD team members involved with both PDs to varying degrees of involvement. The K-12 teachers and faculty/PD team members interacted with each other in different groupings over 19 days throughout the summer of 2014 and the academic year 2014-2015. The same instruments, procedures, and analysis were used with the data collected from all of the participants.

Instrument and Procedures

In this mixed methods study of two K-12 teacher PDs (n=31), both of the PDs (19 days of workshop sessions total over a year) used astronomy as a vehicle for K-12 STEM teachers (comprised mostly elementary and 6th-12th grade science and mathematics teachers) to show, as well as promote with K-12 students, authentic inquiry and STEM research practices while the participants and faculty/PD teams built partnerships. In both PDs, the author/researcher collected pre/post astronomy/STEM Likert-scale perception questions (qualitative) and gathered pre/post

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open-response questions regarding perceptions, as well as took daily journal notes – including informal interviews - on participant and PD team interactions (qualitative). Before the PDs began, and then once they were complete, participants answered eight perceptions Likert-scale questions on a 1 (not meaningful) to 5 (extremely meaningful) scale. Two open-response questions were asked before and after the PDs. There were also content specific questions for the K-12 teachers, which followed a multiple-choice format from the MOSART collection (https://www.cfa.harvard.edu/smgphp/mosart/), but are not the focus of this article, and are not reported here. An external reviewer collected all of the data from the PD workshop sessions.

Data Analysis

The data for this study were collected via three distinct methods: 1) Eight pre/post Likert-scale perception questions (quantitative), 2) Two pre/post open-response perception questions (qualitative), and 3) 19 pages of the author's daily journal (qualitative). The author compared the pre/post responses of all the perception and open-response questions across the entire participant pool (n=10 questions x 31 participants). The total data set includes 310 pre-test and 310 post-test answers. The eight quantitative questions, represented by 248 pre-test and 248 post-test answers, were analyzed for pre/post perception shifts by comparing the frequency of responses on a 5-point Likert-scale. The Likert-scale response of one (1) corresponded to extreme negative sentiment while a response of five (5) corresponded to extreme positive sentiment (e.g. not at all meaningful versus extremely meaningful). The two open-response questions, represented by the remaining 62 pre-test and 62 post-test answers, were coded in conjunction with the author's journal entries for major themes by searching for common words, phrases, and overall meaning in all of the text and then grouping similar answers. While there were a total of 124 open-response answers (62 pre plus 62 post test answers), the qualitative data set is comprised of 512 K-12 teacher written responses since many teachers wrote more than one single open-response answer to each question plus 19 pages of author notes (1 page per day), Many of results discussed below focus on pre/post perceptions of the K-12 teacher participants and as such are presented as both ratios of the total number of participants (n=31) as well as percentages.

Results of Research

Based on the data collected, both of the PDs had an impact on the participant K-12 teachers' perceptions, and the prolonged exposure to the PD content allowed for added K-12 teacher growth in regards to partnerships. For perspective, before the PD workshop sessions, the pre-test results showed that only 16% (5 of 31) of the participants thought that astronomy could be used effectively to teach STEM – specifically science and mathematics - content, and only 26% (8 of 31) thought that the PDs would be useful to increase partnership connections and collaborations beyond the currently established ones.
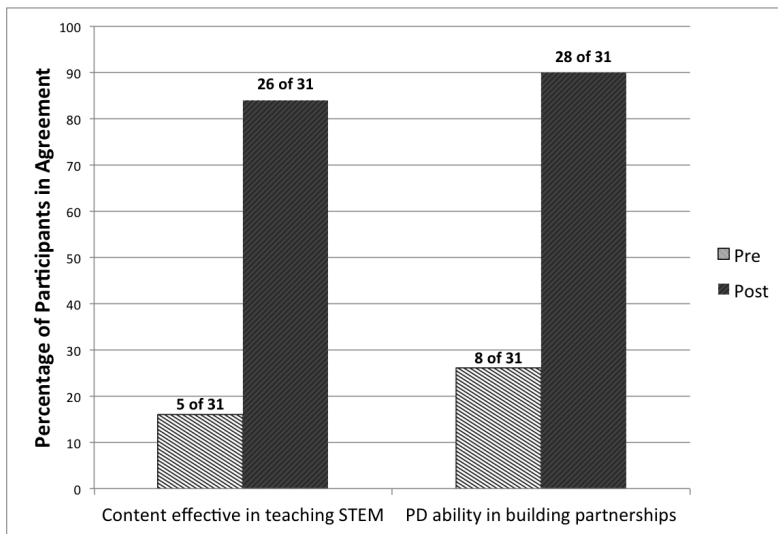
In relation to the first question, "What are K-12 teacher perceptions/use regarding the PD *content* provided," slightly over 90% of the participants (28/31) reported being highly engaged in the workshop sessions (over ¾ of the time) at the end of the PDs. Of all the K-12 teachers, 94% (29/31) rated workshop session events that were inquiry-based and thus involved the K-12 teachers in hands-on activities as 4 (meaningful) or 5 (extremely meaningful) on the 5-point Likert-scale. Feedback comments such as, "[The best thing about today's session was that it was] student-centered and active," "I enjoyed the opportunity to work with materials – hands on – as well as the class discussions on where to integrate the information we are learning," and "It was very hands-on and it made learning understandable" were typical in the feedback to the external reviewer. All (100%) of the K-12 teachers rated the "time to develop STEM lesson plans" as 4 (meaningful) or 5 (extremely meaningful). At the completion of the PDs, nearly 75% (23/31) of the K-12 teachers reported that they anticipated that the PD content

would impact their classroom teaching in the current academic year (2014-2015). While a post survey question analysis showed that 74% of the K-12 teachers were planning to use the astronomy content in their STEM classrooms during the 2014-2015 academic year, another post-test question showed that 84% (26/31) of the participants thought that astronomy could be used effectively to teach STEM. The group's post perception is in stark contrast to their prior perceptions in which only 16% (5/31) of the K-12 teachers thought that astronomy could be used effectively.

The main aspect of the study, however, was to more fully comprehend the systemic nature and context of these PD workshop sessions, and as such, two of the questions – one Likert-scale and one open-response - are explored here in relation to the second research question: "What are K-12 teacher perceptions regarding the PD *partnerships*?" At the conclusion of the PDs, the K-12 teachers responded that the "time spent on STEM lesson planning" was "very meaningful" (score of 5) 94% of the time (29/31 responses), and "meaningful" (score of 4) 6% of the time (2/31 responses). At the conclusion of the PDs, 90% (28/31) of the K-12 teachers thought that the PD workshops would be useful to increase partnership connections and collaborations beyond their currently established relationships. In comparison, the pretest of the teacher's perceptions showed that only 26% (8/31) believed that PD workshops would be useful. The K-12 teachers' overall perceptions are further exemplified through their open-response questions.

One open-response question, which did not prompt for partnership/collaboration or any specific type of response, was "What were the best things about the sessions?" During analysis, the 512 K-12 teacher responses naturally separated into four major themes: *reflection*, *collaboration*, *STEM integration*, and *inquiry*. All of the themes related back to partnership building.

The four themes found in the teachers' open response answers were also found in the author's journal. The author took daily notes (n=1 page x 19 days) during the PDs, and the coded themes are grouped here: 1) As time progressed the K-12 teachers took an increased number of astronomy notes to use for STEM lesson planning [STEM integration]; 2) As time progressed the K-12 teachers interacted with each other more frequently during the activities including lesson planning [inquiry and collaboration]; 3) As time progressed the K-12 teachers held more content specific conversations regarding astronomy [STEM integration]; 4) As time progressed the faculty and PD team interacted with the K-12 teachers more frequently and with less rigidity regarding astronomy content and lesson creation [STEM integration and collaboration]; and 5) The K-12 teachers as well as the faculty/PD team were reluctant to engage in talk of collaboration/partnership and needed prompting by the author to express personal needs and expectations regarding the PD [reflection and collaboration].

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Figure 1: Comparison of pre to post Likert-scale responses regarding astronomy content use in STEM courses and the PD partnership building potential.

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Table 1. Participant open-response comments coded into four major themes.

Theme	Participant Open-Response Answers
Reflection	• "…time to think…," • "Enjoyed the time to reflect on what we have learned…," • "Time for me to reflect on the activities that were done today." • "I could see myself doing these labs with my students," • "It has been wonderful to have time to process the lessons we partake in and be able to come up with lesson plans that we can then implement right away. I have been to several PDs where they fill the entire time with lessons but don't give you time to think about what you've learned."]
Collaboration	• "…being able to discuss with others to fine tune my ideas…" • "Having time to write lessons and collaborate," • "It's helpful to discuss the differences…." • "Enjoying the very good science teachers sharing science. It's great!" • " … just the good communication," • "I liked hearing what others were planning to do in their own classrooms…." • "… discuss ideas with other teachers."
STEM Integration	• "...emphasis on STEM integration," • "…this will give me better background knowledge to understand astronomy better to incorporate astronomy ideas and examples in to my curriculum," • "Knowledge about astronomy that I can use and the ways to connect to Common Core State Standards-based math classes," • "…interesting ways to use technology within the classroom," and • "I have enjoyed learning and observing how the integration process takes place within a unit."
Inquiry	• "I enjoyed the hands on approach of the [activity], being outside and using a fairly large scale… making our own degree measuring tool…and getting a real idea of how the distance to the stars are measured," • "The activities for STEM students! Loved the hands-on ellipse activity and lens/eye activity," • "… sessions were very hands on, made learning about thermodynamics understandable," • "The big data bead activity was my favorite thing we did. [We] took the information and [it] gave us a chance to "see" it work."

With the perceptions of K-12 teachers outlined, the author shifted attention to the perceptions of the faculty/PD team. In relation to the third research question (What are faculty/PD team perceptions regarding the PD *partnerships* with K-12 teachers?), two faculty/PD team member answers during informal interviews exemplified the importance of partnership creation and nurturing. These two faculty/PD team members' comments exemplify the perceptions of the group.

One PD team member reflected,

"The majority of the K-12 teachers seem like they are interested in learning about real-world connections, and the links that experts can bring to them. However, they don't seem to come back for help outside of the PD, even though it's been offered. They want to continue the conversation, but they don't know how to start on a brand new, unexplored subject. Although they aren't at a point where they ask the expert directly, they will contact the [PD] educators, and they are so excited to get to interact with an expert in the room. A lot of the questions that they asked forced me to reflect on how I'm explaining things in general. I think a lot of the [K-12] teachers don't give themselves enough credit, and when they try they can create and do a lot of really cool stuff. I feel like they aren't going to reach out since [the PD is] over. I need to ask what questions they have now to continue a sustained relationship."

A second PD team member expanded,

> "I enjoyed working with the teachers. I especially liked seeing how they went about writing their lesson plans, and discussing with their peers about how to adapt material for their own classrooms. … There was also one case where my first impression of a participant was way off track. One of the participants… exhibited very weak computing skills (such as not understanding how to do certain things in MS Word)… During the school year [though] the teacher exhibited better critical thinking skills, even asking me all sorts of programming questions, and the final lesson plan had to do with programming! Just goes to show that first impressions can be wrong [and you have to keep working with someone to see his/her potential]!"

These two faculty/PD team members echoed the words of the others throughout the PDs with their comments showcasing partnership perceptions.

Discussion

According to both the brief literature review presented earlier and the K-12 teachers' perceptions, effective PD workshop session practices included clear communication, hands-on activities, planned time for reflection and discussion, and intentional partnership building. The data analysis showcases the importance of explicit communication with the participants and between the participants during PDs. Throughout the hands-on activities, intended STEM connections were emphasized (especially in relation to astronomy) and collaboration was encouraged.

The most striking difference was found in the perceptions of the participants in pre to post perception Likert-scale scores regarding STEM classroom use of astronomy content and making partnership connections and collaborations (16% to 84% and 26% to 90% respectively). This growth is the result of the faculty/PD team. They consulted as a group before the PDs began, and incorporated time for reflection and partnership building intentionally for the K-12 teachers. As such, the faculty/PD team explicitly nurtured the perception changes because of the structure within the PD system. The faculty/PD teams emphasized the value of all of the participants in every possible situation and this led to an increase in the K-12 teachers' perception of themselves - an increased self-efficacy - using astronomy content and creating partnerships as a contributing member of the team. Additionally, the author noted in journal entries, that the K-12 teachers wrote ideas in their personal notebooks and on their papers "for later" when they could create lessons and interact with one another, since they understood the importance of the lesson creation and collaboration time. This finding also corroborates the importance of the astronomy content for STEM teachers and the partnership building amongst the K-12 teachers.

In regards to K-12 teacher PD *content* perceptions, based on the Likert scale and open-response perception responses, the teachers expressed a desire to develop lessons using astronomy that they could take back into their STEM classrooms. Recall that all of the K-12 teachers rated the "time to develop lesson plans" as meaningful to extremely meaningful. Nearly three-fourths (74%) of the K-12 teachers reported that they anticipated using content from the PDs in their classrooms in 2014-2015. The idea that a few PD days to a few PD weeks can directly change perceptions regarding content use and partnership building is noteworthy, since the PD system hinges on both.

In regards to K-12 teacher PD *partnerships*, time and structure are needed for K-12 teacher partnership development with each other and faculty/PD team members. For the teachers, lesson planning was a means to facilitate partnership development with all PD members. Nurturing of the partnerships with the K-12 teachers and between the teachers, and the encouragement and valuing of collaborations, is vital from the PD team. The four major themes: *reflection*, *collaboration*, *STEM integration*, and *inquiry* showcase the willingness with which K-12 teachers embrace partnerships during PDs. The themes that emerged from

the author's journal highlight the value of time leading to K-12 teachers' increased content interest, collaborations, discussions, interactions, and initial reluctance to publically express expectations or goals for themselves or others. Noting these characteristics, and building real supports for them, should lead to a more robust PD system. Teachers need time to process information and the author recommends a few hours a day structured for lesson planning and partnership building.

With respect to faculty/PD team *partnership* perceptions, expectations of pedagogy, content, and partnership development must be clear amongst the faculty/PD team before the PDs begin and then discussions must take place during, and after, to achieve optimization of the system. Stakeholders – such as faculty - should appreciate that partnerships with K-12 teachers are often difficult to cultivate and special attention and care – even perseverance – are required for the task. Faculty/PD team members must forgive the missteps of any stakeholder during the PD process, from set-up through follow-up, and look for ways to approach learning with different perspectives.

Overall, the systemic nature of the PDs, iterative in the approach, was important as all of the participants strove to match the created or revised curricula within their communities. The partnerships, or meaningful work with and or each other (Burrows, 2011), hold all participants accountable during and after the PD. The findings of this study agree with those of Hewson (2007) that K-12 teachers need time to plan for future classroom implementation of revised or created curricula. The findings also support Penuel et al.'s (2007) directive for discussions. Moreover, the author agrees with Avalos (2011) that "teachers increasingly are urged to take on tasks such as research in classrooms that traditionally formed part of academia, while teacher educators are requested to develop skills normally defined as belonging to excellent classroom teachers" (2011, p. 17). That the K-12 teachers in the two PDs described in this study were asked to perform inquiry research activities with as much authentic science as possible, and that faculty/PD team members faced challenges of providing excellent pedagogy and content as well providing structure to build participant partnerships, speaks to this role integration.

Limitations of this work include a small participant sample size (n=31), K-12 teacher Likert-scale and open-response questions that did not include direct partnership or systemic nature questions, only one faculty/PD team member perspective for the journal entries, one perspective for this article, and no formal interviews of any participants. Addressing these possible concerns should provide for future studies in how/why the systemic nature of K-12 teacher STEM PDs are structured for participants' maximum content knowledge, perception, and partnership building gains. Continuing the work of others provides a springboard for thoughtful PD construction, and a few lesson plans are available at these websites: http://physics.uwyo.edu/~mike/workshop/index.html and http://www.physics.uwyo.edu/~aschwortz/LASSI/

Conclusions and Implications

Although the study was conducted in the U.S., teacher educators, faculty, and PD team members across an international context must address the *system* of PD development and implementation, as the *system* is critical for the successful future of K-12 teacher continued education through PDs. Global audiences should include effective K-12 teacher PD workshop practices for participants including clear communication, hands-on activities, time for reflection, and partnership building strategies that are intermingled and explicit. Elementary through secondary teachers appreciate and expect solid STEM PD content with a structure that leads to classroom lesson plan development as well as collaboration with their peers. Building a firm, scaffold-supported, yet flexible PD structure is paramount for a fruitful K-12 teacher PD experience. Encouragement of partnership building (with both faculty/PD team and K-12 teachers) is required as participants navigate the PD content. Sustained support for the faculty/PD team and K-12 teachers is essential in terms of both content exchange and opportunities for personal connection. However, the author cautions that rigidly structured PD environments,

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without an opportunity for K-12 teachers to interact authentically – on their own terms and in their own time - and explore various topics through discussion, will hinder partnership building and the strong systemic nature of PDs. A leader of partnerships possibly trained in action research, who can model valuing stakeholders and navigate messy interactions, is needed in PD development and implementation. A malleable PD structure that ensures a sustainable PD *system,* with maximum impact for K-12 teachers' and the faculty/PD team, should feature what is possible through partnerships in all PDs.

Implications for K-12 teacher PD participants that have engaged with a strong system of support for content and partnership building include a higher likelihood of STEM content implementation especially through inquiry, applying STEM integration activities in the classroom, support of peers, and improved self-efficacy as a partnership member. Faculty/PD team implications include valuing real-world examples/inquiry to reinforce STEM integration in K-12 settings, different perspectives in all academic settings, and the power of self-reflection.

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