JSO JOURNAL of STEM OUTREACH

Vol. 1, No. 2, April 2018

The Vanderbilt Scientist in the Classroom Partnership: A Novel Collaborative Apprenticeship Model for Situated Professional Development

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Keywords: Collaborative Apprenticeship, Scientist-Teacher Partnerships

DOI: https://doi.org/10.15695/jstem/v1i1.18

Abstract: The Scientist in the Classroom Partnership (SCP) is a unique program that partners scientists-in-training with classroom teachers to co-teach one day per week in elementary and middle schools. This program has shown positive impacts on all participants, and has the potential to promote professional learning for both the scientists and teachers. The Collaborative Apprenticeship model has been suggested as a unique situated professional development approach for both novice and mentor teachers. The current study examined factors that support the SCP program as a unique Collaborative Apprenticeship (CA) model in which scientists enter the partnership as novice teachers but expert scientists, and teachers bring expertise in pedagogy but are novice scientists. Over the course of participation in the program, the teachers gain scientific content knowledge and grow in their practice, and scientists gain pedagogical skills. Through this unique collaboration, both the scientists and the teachers move through the phases of the CA model (Introduction, Developmental, Proficient, and Mastery) so that by the end of their participation, each grows in a different area of expertise toward mastery.

INTRODUCTION

In 1999 the National Science Foundation (NSF) under the direction of Dr. Rita Colwell launched a unique outreach program called the GK-12 program (Mervis, 1999; Lundmark, 2004). As stated in the GK–12 program announcement, anticipated outcomes included improved communication, teaching, collaboration, and team-building skills for the fellows; professional development opportunities for K–12 teachers; enriched learning for K–12 students; and strengthened and sustained partnerships in STEM between institutions of higher education and local school districts (NSF, 2009; Ufnar et al., 2012). Vanderbilt was one of the first universities to be awarded a GK-12 grant; after seven years of NSF funding, the program evolved into the sustained Scientist in the Classroom Partnership (SCP) in partnership with Metro Nashville Public Schools (MNPS). The program has been incredibly popular for both fellows and teachers, and is now entering its 18th year in MNPS classrooms supported through a combination of funds from MNPS and private donations (Ufnar et al., 2017; Ufnar and Shepherd, in press). A retrospective study of the program using focus groups, interviews, and surveys demonstrated that teachers gained confidence in teaching science as well as enhanced science content knowledge. Fellows reported enhanced communication, mentoring, and teaching skills that assisted them in their careers (Bolger et al., 2012).

While the original GK-12 program and subsequent studies focused primarily on providing graduate students (fellows) with teaching and mentoring skills that they would need in their future science careers, we recognized several teacher-related outcomes in our program that were not the original focus of the GK-12 program. First, as noted in our studies as well as others, pairing fellows with teachers led to an increase in teachers' confidence in teaching inquiry-based science, as well as increasing the depth of their science content knowledge (Gamse et al., 2010; Van Hook et al., 2009; Husiak-Clark et al., 2007; Ufnar and Shepherd, in press). Teachers, particularly, at the K-8 level often find themselves struggling to teach science in an inquiry-based manner and to effectively integrate hands-on activities into their instruction. Several reasons could be pointed to as explanations including lack of science content knowledge and the ever-changing scientific landscape, making it difficult for teachers to keep up with current science content (Haney and Lumpe, 1995; Garet et al., 2001; Loucks-Horsley et al., 2003). Further, there are few professional learning opportunities for K-8 teachers to increase their science content skills, and those available tend to focus on pedagogy rather that content (Supovitz and Turner, 2000; Justin, 2004; Yoon et al., 2007; Darling-Hammond et al., 2009). Testing pressures also tend to constrain teachers' ability to do hands-on or inquiry-based laboratories (Musoleno and White, 2015). Further, too many professional development (PD) programs for teachers are not sustained over long enough periods of time and/or lack sufficient time to provide adequate gains in knowledge or confidence (Darling-Hammond et al., 2009).

Similarly, programs that train graduate students and postdoctoral fellows often focus exclusively on scientific research, with few if any opportunities to hone their teaching or communication skills (Aanerud, et al., 2006). Additionally, increasingly limited funding for science is leading PhDs to seek training for careers in areas other than research (Doyle and Vale, 2013). For those scientists interested in a teaching career, either at the K-12 or collegiate level, there is a lack of effective and accessible training mechanisms for preparing scientists for the demands of the classroom environment (Sauermann and Roach, 2012; Doyle and Vale, 2013). Thus, the GK-12 program was able to bridge the gap of the two problems initially identified by Dr. Colwell: the lack of sufficient numbers of highly qualified K-8 science teachers and the shrinking job opportunities for science PhDs, by offering teaching opportunities to graduate students to enhance their PhD training.

As the SCP program has matured and developed over the past 17 years, it has become increasingly apparent that both fellow and teacher participants gain tremendous skills that translate to growth in their career (Ufnar et al., 2017; Ufnar and Shepherd, in press). In the SCP program, teachers and scientists are partnered together for a full year to co-plan and co-teach one day per week in the upper elementary and middle school classroom. During the summer, they work together for a week to build the partnership, design curricula, and learn how to co-teach. During the academic year, they implement the curriculum in the classroom (Ufnar et al., 2017). As their collaboration continues throughout the year, each partner takes on more and more of the identity of their partner. For example, fellows learn how to communicate their sophisticated science knowledge to young students, and teachers learn new and exciting science content that would not be possible given their time challenges (Trautmann and MaKinster, 2005; Ufnar and Shepherd, in press).

In examining the SCP in its current form, we realized that it has very similar characteristics to a model described in the literature called the Collaborative Apprenticeship (CA) model (Glazer and Hannafin, 2006). The CA model was proposed to explain the professional growth that occurs over time between pre-service and mentor teachers. Based on professional growth models that include situated learning in a community of practice (Lave and Wenger, 1990), situated cognition (Brown et al., 1989), and reciprocal interactions between teachers (Wenger, 1998), the CA model describes the growth of the preservice teacher from novice to mastery while learning from the mentor teacher, and the same transition for the mentor teacher from novice to mastery as he/she gains new theoretical knowledge. The SCP CA model proposed in the current study is unique in that fellows and teachers working together in a mutually beneficial apprenticeship as content experts (fellows) and pedagogical experts (teachers); (Stamp and O'Brien, 2005; Trautmann and MaKinster, 2005; Gengarelly and Abrams, 2009; Ufnar et al., 2017) transition over the year-long intervention toward becoming experts in both pedagogy and science content. We posit that the SCP CA model is a unique outreach program that acts as an impetus for change in the science classroom, and drives the positive impacts seen for fellow and teacher participants (Ufnar et al., 2017), resulting in a stable, highly successful professional learning model. To examine this hypothesis, we used coding analysis of interviews of three fellow-teacher teams to determine 1) what attributes define a good fellow or teacher or team for the SCP program; 2) do scientists and teachers grow professionally as a result of working with their SCP partner; and 3) does the SCP program represent a unique CA model that could provide effective in-classroom professional development for both teacher and fellow participants.

RESEARCH DESIGN

Data Sources. A multiple case study approach (Yin, 2003) was utilized for this study to identify attributes of participants in the SCP program. The multiple case study approach was chosen to define the parameters required for subsequent studies, and to determine the feasibility for elucidating the factors necessary to define the SCP program as a unique collaborative apprenticeship model both within each case and across all cases. The primary source of data in this case study was semi-structured interviews of three different teacher-fellow pairs (interviewed separately) conducted by the first author. The semi-structured interview, as a hybrid of the structured interview method, was chosen to allow research participants the ability to offer different perspectives to the study focus (Galletta and Cross, 2013). Interview questions (Table 1) focused on eliciting information to inform the research questions to determine if the SCP model represents a CA model for professional learning between teachers and scientists within the SCP partnership. As semi-structured interviews have the potential for bias, the interviewer relied on a high-level of reflexivity during the interviews (Galletta and Cross, 2013) to reduce potential bias. All instances that had the potential for interference were identified and noted. These instances were removed from the interview transcripts before or during the coding analysis. The interviews were audiotaped, transcribed, and formatted into instances

Table 1. *Fellow and Teacher Interview Questions*

Teachers	Fellows
What attributes do you think make a good fellow?	What attributes do you think make a good teacher?
What do you think you have learned from having a scientist?	What do you think you have learned from your partner teacher?
What do you think your fellow has learned from you as a teacher?	What do you think your teacher has learned from you as a scientist?
At what point do you think you could step out of the classroom and leave the fellow "in charge"?	At what point do you think you could handle the classroom by yourself?
How do you feel you have grown in your practice after your time with your fellow?	How have the teachers changed since you have been their partner fellow?
How would you describe your collaboration – i.e. what does it look like in the classroom?	How would you describe your collaboration – i.e. what does it look like in the classroom?
How would you describe your collaboration outside the classroom during planning?	How would you describe your collaboration outside the classroom during planning?
What do you think is most important for an effective collaboration between a scientist and teacher?	What do you think is most important for an effective collaboration between a scientist and teacher?

for coding analysis. The research team consisted of the first author and two independent analysts. The research team focused on coding the interview data for analysis.

Participants and Settings. Three fellow-teacher teams were selected to participate in the case study to examine the key characteristics and elements necessary for a collaborative apprenticeship. As part of the program, only teachers with strong classroom management are chosen for the program; there is no requirement for science content background. All of the teachers in the SCP program teach science in high needs urban schools in the southeast United States, and all have been in the classroom for at least three years. Fellows are chosen for the program based on their interest, and if they have progressed to a stage in their graduate program such that their research is not affected by coming out of the laboratory one day per week. Fellows are allowed to participate if they are in a master's, doctorate, or postdoctoral training program. The SCP program is a supplemental, rather than required, component of the fellow's training.

All teams were paired together in the summer before participation, with the SCP director matching fellows and teachers by personality and science and pedagogical backgrounds (Ufnar et al., 2017). Throughout the 17 years of the program, over 90% of pairings have resulted in strong, well-matched teams. The three teams for the current study were chosen from the current cohort of eight teams and are representative of the over 100 teams that have participated in the SCP program. The teams were chosen based on the length of participation in the program (one, two, or three years) to elucidate any potential differences based on time in program. A description of each of the teams is included below.

Team 1: Trudy (teacher) and Paul (fellow) are in their first year of the SCP program and co-teach in a 6th grade science classroom in an urban middle school in the southeastern United States. Trudy has taught science for over 20 years and is a dynamic teacher who has implemented hands-on laboratory activities in her classroom throughout her entire career. She has little science content training but has a very strong background in pedagogy. Paul has a PhD in biochemistry and is currently a postdoctoral fellow in a southeastern university.

Team 2: Carrie (teacher) and Cathy (fellow) co-teach in a STEM class for 5-8th grade students and are in the second year of the SCP program. Carrie has taught middle school science for 14 years. She is a charismatic teacher in the classroom and is well-liked by her students. For most of her career, she has taught 8th grade science and physical science, and currently teaches 5-8 STEAM related arts classes at a high achieving, high minority middle school that tracks to one of the district magnet high schools. She has the most science training of the teachers in the program with a B.S. and M.S. in biology with experience in molecular biology. Her current fellow, Cathy, has been her partner fellow for the past two years. She has a PhD in molecular genetics and is currently a postdoctoral fellow at a southeastern university.

Team 3: Mary (teacher) and Jack (fellow) have co-taught in a 4th grade science classroom in the SCP program for three years. Mary has 24 years of teaching experience, and is a dynamic and effective teacher. She is K-6 trained and has little science content training. She is an expert in pedagogy who regularly acts as a mentor to new teachers in her school. She has taught all subjects in all elementary grades. Jack is currently a PhD candidate in microbiology at a southeastern university.

All teacher-fellow pairs worked together in the SCP workshop each summer of participation as described previously (Ufnar et al., 2017). Briefly, the summer workshop component consists of relationship development between the teacher and fellow, development of collegial interactions among and between the teams, planning of hands-on and inquiry-based lessons for the academic year, and enhancement of science and pedagogical skills of the participants (Ufnar et al., 2017). During the academic year, the fellow co-teaches and co-plans with his or her partner teacher for one day per week. The teachers and fellows can and do participate for more than one year.

Coding Analysis of Interview Responses. To answer the research questions, the Grounded Theory method (Glaser and Strauss, 1967; Strauss and Corbin, 1990) was used to create and analyze the themes that emerged from coding. Instances were initially categorized by concepts, and then assertions were generated from the categories of codes (Table 2). The research team identified the posited assertions to explain the codes and formulated a theoretical model that describes the SCP program as a CA model and the requirements necessary for defining the SCP as a CA model. To show the SCP model as a reciprocal professional growth model for scientists and teachers, the SCP coding scheme was compared with the CA model coding scheme developed by Glazer and Hannafin (2008) as described below.

A total of 415 instances from teacher and fellow interviews were coded by the research team using a modified version of the coding scheme developed by Ufnar et al. (2017). Coding was used to determine the attributes that would define a good fellow or teacher for the SCP program and whether or not scientists and teachers grow professionally as a result of working with their SCP partner. Modification of the original coding scheme was accomplished by adding or eliminating categories as needed to capture emergent themes from participant comments; the resultant scheme is shown in Table 2. Stability of the coding scheme was determined when the research team achieved an inter-rater reliability of 87%, 80%, and 80% for the primary, secondary, and tertiary codes, respectively. Based on the coding analysis, 94% of the coded instances fell into two of the primary coding categories: Partnership and Insight. Therefore, the coding

Table 2. *Coding scheme developed for analysis of fellow-teacher interviews*

1° Code	2° Code	3° Code	Description
Partnership (P)	Fellow Brings Resources (FR)	Fellow Content Knowledge (FCK) Materials (FM) Extra Hands (EH)	The fellow brings materials, research experience, specialized knowledge, and/or lessons based on research to the partnership
	Teacher Brings Resources (TR)	Pedagogical Knowledge (TPK) Classroom Management (CM)	The teacher brings knowledge of classroom management, pedagogical techniques, and/or understanding of student dynamics and needs to the partnership.
	Hands-on/Inquiry Science (HOS)		The fellow and/or teacher brings more hands-on and inquiry instruction to the classroom.
	Classroom Collaboration (CC)	Respect for Partner (RP) Co-teaching (CT) F-T Relationship (FTR) Planning (PL)	The teacher or fellow describes the value of their partner as a mentor or colleague, their personal relationship, the importance of mutual respect as a co-teacher in the classroom or the value of planning in the partnership – either in the classroom setting or outside the classroom.
Insight (IS)	Fellow Professional Development (FPD)	Classroom Management (FCM) Pedagogical Knowledge (FPK) Adaptability/Flexibility (AF) Respect for Partner Career (FRC) Time Management (TM) Relationships with Students (RS) Communication to Different Audiences (CDA)	Fellows describe how they learned about teaching from their partner or gained experience through the program in learning to communicate to different audiences, time management, pedagogical skills, adaptability/flexibility, and respect for their partner's career.
	Teacher Professional Development (TPD)	Growth in Practice (GP) Content Knowledge (TCK) Adaptability/Flexibility (AF) Respect for Partner Career (TRC)	The teacher describes how participation impacted his/her teaching practice, content knowledge, connection to the scientific community, confidence, and understanding of research demands.

scheme shown in Table 2 includes the two primary codes with modification of the original secondary and tertiary categories as required through initial coding analysis of the instances. The primary and secondary themes remained from the original, with only the tertiary themes altered as necessary for the current data.

Confidentiality of Data. All participants in this study were consented through procedures approved by the lead university Institutional Review Board. Consent documents were scanned and maintained on a password protected server. All interviews and transcripts were kept on a password protected server. All paper records were kept in locked file cabinets. All names have been changed to protect confidentiality.

RESULTS

Analysis of Instances. Ninety-four percent of the 415 instances coded from the six interview transcripts (three each teacher and fellow) fell into the two primary codes of Partnership and Insight. The predominant tertiary codes with eight instances or more are shown in Figures 1A-1C. The predominant themes that emerged from the Partnership code were co-planning (PL), co-teaching (CT), and the relationship between the fellow and teacher (FTR) under the secondary category of Classroom Collaboration; and fellows bringing content knowledge (FCK) to the partnership under Fellows Bringing Resources. Hands-on or inquiry-based science (HOS) was mentioned regularly throughout the interviews. Teachers gaining content knowledge (TCK) was the major theme identified in the Teacher Professional Development category within the Insight code. The ability of the teacher to adapt and grow in her practice (GP) was also discussed throughout the interviews. As part of fellow growth, the gain in pedagogical knowledge (FPK) and ability to adapt to situations and relationships (AF) were seen as the most often mentioned. Several other themes were mentioned occasionally including the ability of the fellow to form relationships with students (RS); grow in classroom management techniques (FCM) and learn pacing and time management (TM); and how to communicate with different audiences (CDA).

Coding Analysis of Teacher and Fellow Instances. Analysis of the coding data comparing teacher and fellow responses showed that both teachers and fellows discussed several of the instances in an approximately equal manner (Figure 2). Those that fell out as equally important were co-planning (PL) and co-teaching (CT). Both teachers and fellows stressed the importance of successful co-teaching and co-planning in the execution of the weekly curriculum implementation. Teachers and fellows also discussed fellows gaining pedagogical knowledge (FPK) and classroom management (FCM) and communication skills (CDA), as well

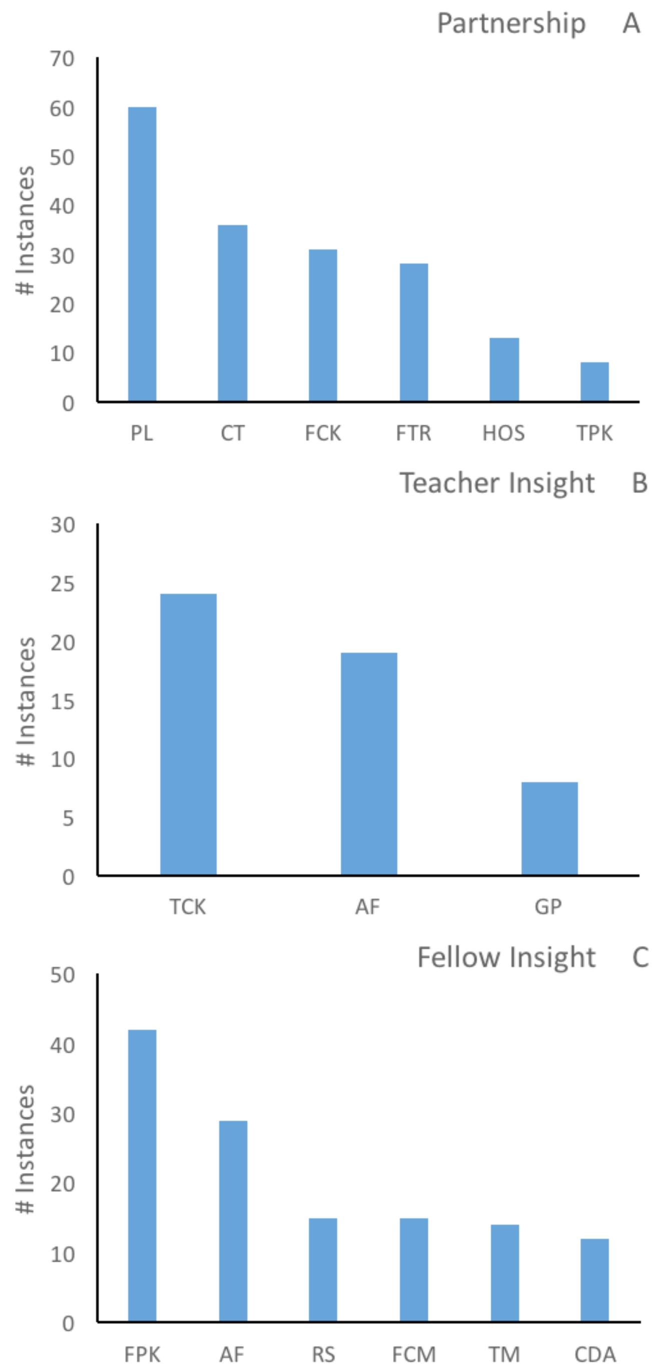

Figure 1A-1C. Number of Instances for the Secondary and Tertiary Codes within the Partnership and Insight Primary Codes of the SCP Coding Scheme. The 415 instances were coded by three independent researchers. Consensus codes were assigned and quantified for Partnership and Insight. Only those with greater than eight instances were included in the figure. 1A=Partnership; 1B=Insight (Teacher); 1C=Insight (Fellow). PL=co-planning; CT=co-teaching; FCK=fellow content knowledge; FTR=fellow-teacher relationship; HOS=hands-on/inquiry science; TPK=teacher pedagogical knowledge; TCK=teacher content knowledge; AF (T or F)=adaptability and flexibility; GP=growth in practice; FPK=fellow pedagogical knowledge; RS=relationship with students; FCM=fellow classroom management; TM=time management; CDA=communication to different audiences.

as teachers gaining content knowledge (TCK) as important outcomes of the SCP program as a successful professional learning environment for both teachers and fellows. Interestingly, the teachers discussed the relationship between the teacher and fellow (FTR) and respect for their partner (RP) more often than fellows, although both indicated that the fellow/teacher relationship is essential to the success of the program, with one fellow stating that “the relationship is the most important component for a successful program.” While fellows did discuss the requirement of a fellow to be adaptable in the relationship (F-AF), teachers more often stressed being adaptable to the ever changing classroom environment as a necessity to a successful partnership. Mentor teachers, as veterans in the social-emotional learning needs of the students, discussed the fellows’ ability to relate to the students and develop relationships with the students (RS). Without this relationship, there would be no trust built with the students, and the fellow would not be given enough re-

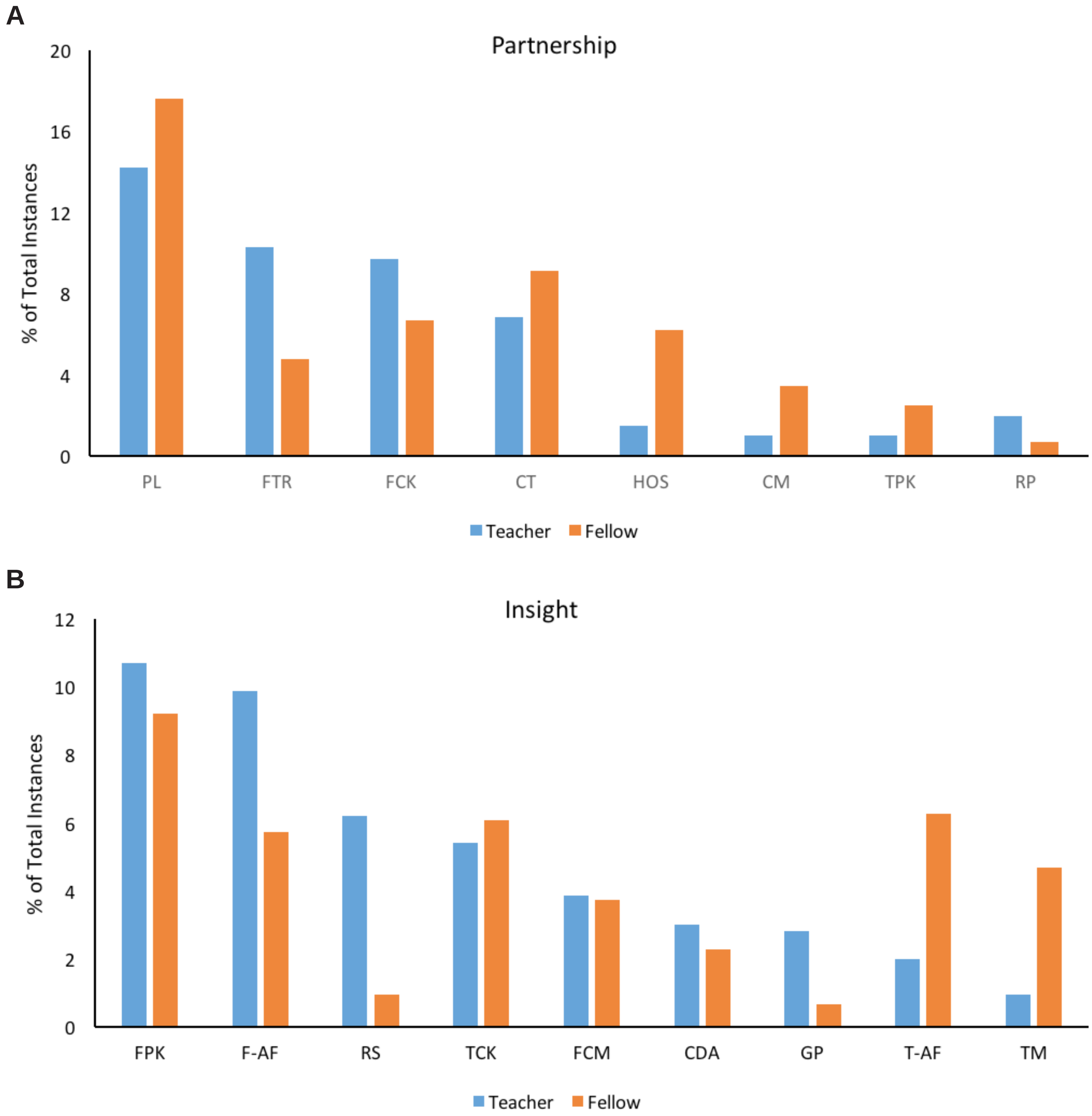

Figure 2A-2B. Comparison of Coded Instances between Teachers and Fellows – Percent of Total Instances. Instances were assigned to secondary and tertiary codes within Partnership and Insight as described for Figure 1. Only those codes with greater than 9% of the total instances are included in the figure. FCK=fellow content knowledge; PL=co-planning; CT=co-teaching; FTR=fellow-teacher relationship; F-AF=adaptability and flexibility (Fellow); FTM=fellow time management; RS=relationship with students; TCK=teacher content knowledge; T-AF=adaptability and flexibility (Teacher).

spect (Watson and Ecken, 2003). With the relationships developed in the classroom, the fellow gains the respect of the students and acts as a science mentor (Ufnar et al., 2017). The teachers were very open about the fellows bringing new content knowledge (FCK) to the partnership as a strength of the program, and felt that it helped the teachers grow in their practice (GP). One teacher stated “I have learned to look at the big picture things…instead of teach the skill.”

Fellows, on the other hand, talked about being able to bring more labs into the classroom (HOS), and stressed the importance of the teachers bringing strong pedagogical knowledge (TPK) and classroom management (CM) to the partnership. Fellows more often discussed the ability of a teacher to be adaptable and flexible, rather than speaking of themselves as such. In fact, some fellows felt that a scientist naturally comes in “ready for anything” as compared with a teacher who is used to running her own classroom. Interestingly, fellows also discussed their growth in learning time management skills because of their participation in the program. One fellow stated that he now “gets the same amount of research done in four days that used to take five.” He and the other fellows attribute this to learning pacing in the classroom environment.

As the fellow/teacher pairs were chosen based on how long they had participated in the SCP program, this study also examined whether time in program impacted the fellow-teacher responses. The three teams included in this study worked together for a different number of years: team one (one year); team two (two years), and team three (three years). We examined the themes that emerged from the codes based on time in program, teachers versus fellows, and overall themes. One interesting component that emerged from the analysis of the coding was that the partners (both teachers and fellows) felt that the most growth occurred in the first semester of working together, with gradual and continual growth occurring throughout their time in the program. The most significant growth during this time is in the development of the relationship between the fellow and the teacher and learning how to “relax”, both with each other and in the classroom (adaptability/flexibility), and to be open to growing in the practice. As they co-teach over the course of the academic year, the team continues to develop skills such as problem-based learning (fellow), increased content knowledge (teacher), and pedagogy and classroom management skills (fellow). Throughout the second and third years of participation, the fellow-teacher teams go through a period of refinement and strengthening of the partnership.

Emergent Themes from Coding Analysis. Several themes emerged from the coding analysis that provide evidence to help answer the research questions (Table 3). The emergent themes that indicate growth of teachers and fellows in the SCP program are co-teaching, co-planning, the teacher gains content knowledge from fellow, and the fellow gains pedagogical knowledge from the teacher. The themes that suggest attributes necessary for a good fellow, teacher, or team are fellow-teacher relationship; adaptability/flexibility as a necessity for an optimal partnership; the fellow brings content knowledge to the partnership; and the teacher brings pedagogical knowledge to the partnership (Table 3). These themes are described in greater detail below.

Co-teaching and co-planning. Co-teaching and co-planning, built on a strong foundation of the fellow-teacher relationship, emerged as the lens through which the teachers and fellows learned content and pedagogy from each other. The planning consisted of summer and academic year planning, and in- and out-of-classroom planning time. The teachers and fellows would co-plan lessons that they would implement in the classroom as a co-teaching team (Ufnar et al., 2017). The teacher and fellow share the responsibility for planning and teaching of the lessons, managing the classroom, and assessing the efficacy of the lesson. Fellows and teachers described the co-teaching as requiring a “teamwork” or “tag-team mentality” in which the teacher and fellow have respect for each other and their expertise. The fellow has to understand how the teacher runs the classroom, and the teacher respects that the fellow will work within that system. The teacher and fellow must have compatible teaching styles and be able to build on the other’s expertise in the classroom and during planning.

During co-planning and co-teaching, the fellow and the teacher follow a method involving reciprocal interactions presented by Glazer and Hannafin (2008), including brainstorming ideas, back scratching, discussing and resolving conflict, storytelling, giving and seeking advice, modeling, sharing ideas, motivating each other, and posing and responding to questions. The teachers described brainstorming in planning meetings, and discussed the challenges and successes of different lessons developed and implemented. Fellows and teachers discussed the necessity of more explicit planning sessions in the beginning of a partnership to ensure that they knew what they were going to teach and who would be teaching the different parts of the lessons. The participants described knowing what the teacher would teach before and after the fellow and teacher co-taught the lesson, and the necessity of being open to change if they needed to reteach a concept. Both described challenges to co-planning, specifically with time management and fellow research requirements. Both discussed being open to helping each other out with the lesson so that the planning doesn’t always fall on one or the other’s shoulders. As one fellow put it, “the first class is really the guinea pig class…I’ll make it work [scientifically] and she’ll [the teacher] make it pretty.”

In the classroom, the teachers and fellows worked together to present the lesson in a fun, engaging way that would still allow the students to learn the concepts. During the lesson, they felt that they had to be comfortable interrupting when necessary to help each other clarify points, but not at the expense of disrespecting their partner. The fellow and teacher felt that they knew each other well enough by the second month working together that they could jump in as necessary, and by the second year, they had nonverbal signals that they would use to know when to add to the lesson. Initially in the co-teaching, the teacher was the leader in the classroom and began to act as facilitator by the second semester. The fellow acted as the "assistant" to the teacher until comfortable in leading the lessons. The teacher and fellow both described the need to use several different examples (from both the teacher and fellow end) to make the content more understandable. Both groups discussed being able to bounce ideas off of one another during the co-teaching, and diverting questions to the other when the other's expertise lent itself better to answering the question.

Fellows bring content knowledge - teachers gain content knowledge. Themes that emerged from this study show that during the co-planning and co-teaching, teachers and fellows learn from each other – teachers learn content and fellows learn pedagogy. The fellow, as a STEM graduate student or postdoctoral fellow, brings a higher level of content that the teacher does not possess. Bringing in content allows the teacher to gain new content knowledge, along with seeing how this content can be adapted to the K-8 audience as authentic real-world learning. Many of the fellows and teachers commented that fellows modeled real-world examples during co-teaching and increased effective use of lab notebooks in the classroom. Further, the teachers gained in-

Table 3. *Emergent Themes from Coding Analysis*

Research Question	Emergent Theme	Example Quote
Growth of Fellow and Teacher as Result of Partnership	Co-teaching	The teacher says "hey I've never heard that before." She says that a lot, and sometimes just for fun. But it's also to get me to say something else in my lesson that she actually didn't know. (F)
	Co-planning	I come up with what is possible and she comes back with what is feasible (F) I think a good teacher is willing to plan with the scientist so then there is a tag-team mentality when it goes to the education of the students. (T)
	Teacher gains content knowledge from fellow	I've learned content just listening to him teach content; I think it's good for the kids to see me learn as well as the kids. (T)
	Fellow gains pedagogical knowledge from teacher	One of the biggest things I have learned is classroom management. She knows how to maintain her classes, and figuring out what pieces will work for me. (F) I think the fellow reading the students and how to present the information and how to make sure they've retained it is huge. (T)
Attributes of a Good Fellow, Teacher, or Team	Fellow-teacher relationship	There's a respect on both sides. (T) There is a lot of trust because you're willing to learn from each other regardless of the degree or lack thereof. (T) A good teacher is willing to share the classroom. (T) You have to complement each other as far as your abilities. If you both do the same thing, you won't have the whole effective picture. (F) There's a lot of trust; you're willing to learn from each other regardless of degree or lack thereof. (T)
	Adaptability/flexibility as necessity for optimal partnership	…and to remember to make each other laugh, even when we are stressed about lab work or class work (T) If you can't go with the flow, it's just not going to work out. Things rarely ever goes as you expect. (F)
	Fellow brings content knowledge	I have learned tons of science. We call them his CSI skills – and I learned a lot about owls today! (T) I related it to a baseball field. I did angles, saying you know it's 45 degrees from first to second. The teacher said, "I didn't even think of that." (F) He really applies to the real world where I don't have that much in depth. It's an incredible opportunity for these kids. (T)
	Teacher brings pedagogical knowledge	If there is a certain worksheet she prefers, I usually defer because she recognizes the capability of the students. (F) She's taught the science concepts for fourth grade and she knows what should be covered. (F)

formation about new advances in the sciences and research that the teacher "cannot keep up with" during discussions with the fellows. Both teachers and fellows noted that the fellows could think of real world examples during the class (on the fly) that the teachers would "never have thought of." The teachers felt that they had the basic knowledge to impart the content, but they struggled with making it interesting and relevant to real-world contexts. The fellows could also go into more depth with the students about certain topics because of their expertise. Teachers commented that the fellow brings a new perspective to the science classroom that the teacher cannot. One teacher described the ability of the fellow to relate their lesson about predator-prey relationships to the Trolls movie that he had seen because he could make the connections between a children's movie and the scientific concepts. The teacher mentioned that she would never have thought of the connection, even after having seen the movie. These examples demonstrate the scientific savvy that the fellow possesses that he or she is now transferring to the teachers and students.

The teachers and fellows described teachers learning new content from the fellows during both co-teaching and co-planning. In the classroom, one fellow said that he teaches the first class, and "by the end of fourth period", the teacher can teach the content on her own. Another fellow described the teacher asking him questions about the content in the beginning of their partnership because she did not know the answers. This gave her students the ability to see her learning along with them. Now, however, after two years, the teacher is able to ask those questions during class for her students to prompt the fellow, but both members of the team know that she also now has the ability to answer these questions. Interestingly, all teachers and fellows discussed the content knowledge that fellows brought and teachers gained, but fellows were more reticent about feeling that teachers actually learned from them. They felt that they had learned much more than the teachers. Teachers, on the other hand, discussed the pedagogy that the fellow learned, but they were very open about the content learned from the fellow.

Teachers bring pedagogy and classroom management – fellows gain pedagogy and classroom management. Teacher participants are recruited for the SCP program from the more established teaching ranks, bringing with them a wealth of knowledge in pedagogy and classroom management practices. The teachers are skilled at classroom management, understanding of standards, planning, lesson development, pacing, how students learn at the different levels, strategies for content implementation, and differentiating the learning to reach all audiences. Alternatively, the fellows come in with little to no knowledge of the K-12 system, pedagogy or classroom management. The summer training consists of a week-long workshop that covers the basics of pedagogy, planning, and curriculum development, but does not cover classroom management (Ufnar et al., 2017). The fellow gains all of the necessary classroom management and pedagogy in the classroom as the apprentice to the teacher. In the beginning of the partnership, the fellow observes as the teacher models lessons and classroom management. The teacher and fellow are consistently planning throughout, and the fellow moves from the observer to an assistant. By the third week in the classroom, the fellow is participating in the teaching, and the teacher will bring the fellow in more often until the fellow is comfortable leading a lesson.

The teachers and fellows both felt that it took the fellows one semester to become relaxed and comfortable enough in the classroom that if the teacher needed to step out for a moment, this could happen without chaos ensuing. The fellows all felt privileged to learn from their mentor teachers, adding that they had learned much more than their teachers. Although each had taught at the university in one capacity or another (teaching assistantship, etc.), they recognized the significant differences between the K-12 and university levels. For instance, several fellows were amazed at the requirements for the standards, and how much emphasis was placed on the standards by the teachers and administration in the K-12 environment. They all commented (both teachers and fellows) about the fellows' lack of knowledge about pacing in lesson planning. The fellows discussed the realization that they "are never able to make it through a lesson… and to be ok with that." The fellow in the beginning year of the program mentioned this, but said that he works with his teacher to perfect the plans. He "comes up with the ideas and she teaches him how to implement" those plans. The fellow in the second year of the program discussed pacing and working with the teacher to make sure they get the important points covered in a short amount of time. The fellow in his third year had the most maturity in his understanding of time management in the classroom. He discussed how he initially had to send everything to his teacher for input, but that he is now strong enough in the classroom that she hardly has to look at his lesson plans before they implement them. Interestingly, two of the fellows mentioned that growth in pacing in the classroom environment had actually helped them to pace themselves in the research laboratory. One fellow mentioned that he is getting the "same amount of work done… with one less day in the lab."

All fellows were very specific about the need to have an experienced teacher in the room to manage the classroom. One fellow worked with a new teacher for a short period of time in his second year, and he noticed the challenges that he encountered with that teacher as opposed to his normal classroom teacher. The teachers and fellows mentioned specific classroom management techniques that the fellows would mimic "after watching" the teachers model the techniques in the classroom. One teacher mentioned that her fellow would only use the "clapping" technique in the beginning, but now that he has seen her model several different techniques, he uses those interchangeably.

All of the fellows commented that they learned through “watching their teachers” interact with the students. Some of the fellows were natural in their ability to communicate with different audiences, but most learned from teachers modeling the behavior. The fellows were able to create relationships with the students, which allowed them to learn about their backgrounds, their interests, and their challenges. The fellows felt that by their second semester, they were able to present a lesson to the teacher that only needed minimal revision, and that by the second year, teachers noticed that the fellows were able to completely scale the content for the specific audiences, and differentiate the learning for the classroom. By the third year, one fellow-teacher pair mentioned that the fellow began to teach the mentor teacher new pedagogical techniques, such as how to incorporate the science content into new lessons. Interestingly, all teachers felt that they had also grown in their teaching practice through the SCP program. One teacher mentioned that she was “more flexible” and “less structured” in the classroom after working with a fellow, and all teachers mentioned that they felt “renewed” and “have more fun” with the labs through working with a fellow.

SCP and CA Coding Scheme Comparison. The primary category of reciprocal interactions from the CA coding scheme (Glazer and Hannafin, 2008), which includes storytelling, backscratching, discussing and resolving conflict, brainstorming, giving and seeking advice, modeling, sharing ideas, motivating, and posing and responding to task-based questions, are defined as “interactions demonstrating and influencing a mutual relationship supporting teacher learning and development” (Glazer and Hannafin, 2006). In the current study, we describe reciprocal interactions through the actions of co-teaching and co-planning, the development of a relationship between the fellow and teacher, and the professional growth of the fellow and teacher through modeling content, pedagogy, and classroom management. To show the similarity between the two environments, and to show that the studies ascribe to the same definition of reciprocal interactions, a comparison was performed (Table 4) between the two coding schemes used for the SCP model (Table 2) and the CA model (Glazer and Hannafin, 2008). This study uses a similar definition as Cook and Friend (1995) which states that co-teaching is “when two or more professionals deliver substantive instruction to a diverse or blended group of students in a single physical space”. In this case, the two professionals are a licensed teacher and a graduate-level scientist. Co-teaching, along with co-planning and the relationship between the fellow and teacher as integral components of co-teaching, allows the teacher and fellow to share beliefs and understanding of the learning potential of students; influence the environment of the classroom; create a relationship built on trust and respect; work together in close proximity with shared time, tasks, and resources; and work within the team as a separate but valued person. These factors that are shared in the co-teaching environment are

Table 4. *Alignment of Emergent Themes from SCP Model and Reciprocal Interactions from the CA Model*

CA Model Reciprocal Interactions	SCP Model Emergent Themes	Example from SCP Model
Storytelling	Co-teaching; Co-planning	Teacher and fellow tell stories about their planning and teaching
Back-scratching	Fellow-teacher relationship	The fellow will bring a kit to the classroom, and they will share responsibilities to get everything ready for the lesson
Discussing/resolving conflict	Co-teaching; Adaptability/Flexibility	Teacher and fellow address issues that occurred in the classroom and offer solutions
Brain-storming	Co-planning	The teacher and fellow co-plan the lessons
Giving/seeking advice	Teacher learns content from fellow; fellow learns pedagogy from teacher; fellow brings content; teacher brings pedagogy	Fellow will suggest a different real-world example to use (content); teacher will advise fellow about the best way to present a lesson
Modeling	Teacher learns content from fellow; fellow learns pedagogy from teacher; fellow brings content; teacher brings pedagogy	Teacher models pedagogy; fellow models content
Sharing ideas	Co-planning	Fellow shared the example about the movie, *Trolls*, for a specific lesson
Motivating	Teacher learns content from fellow; fellow learns pedagogy from teacher; fellow brings content; teacher brings pedagogy	Fellow complimented the teacher on growth in content; teacher complimented fellow on class-room management gains
Posing/responding to questions	Co-teaching	Fellow asked the teacher how they could revise a lesson to make it better for the students

common to both the SCP model and the CA model, with the CA model listing these traits as factors affecting reciprocity (Glazer and Hannafin, 2008). Further, themes found within co-teaching and co-planning such as brainstorming, storytelling, back scratching, discussing and resolving conflict, giving and seeking advice, modeling, sharing ideas, motivating, and posing and responding to questions are all classified as reciprocal interactions in the CA Model (Glazer and Hannafin, 2006). These reciprocal interactions are also exemplified by such themes in the SCP model as fellows and teachers bringing resources to the partnership including content knowledge (fellows) and pedagogical knowledge (teachers). In the SCP coding scheme, these themes fall under the primary category of partnership, and align with both the reciprocal interactions category and the factors affecting reciprocity category (Table 4).

Under the insight category in the SCP coding scheme, several themes emerged that align well with the reciprocal interactions and factors affecting the reciprocity category (Table 4). The relationship between the fellow and teacher is developed during the summer workshop and continues throughout the partnership. As part of this relationship, fellows and teachers must be flexible and adapt to both different personalities and changes in the classroom and planning. Therefore, teacher and fellow adaptability and flexibility within the Insight code fulfill the necessary requirements of discussing and resolving conflict, affect, beliefs, environment, and personality within the reciprocal interactions and factors codes. Teacher and fellow growth (both in content and pedagogy) showed significant overlap with the secondary codes within the reciprocal interactions category (listed above). The fellow shares new content with the teacher through stories, assisting in task completion brainstorming sessions, assisting the teacher with difficult content, sharing ideas, modeling strategies in the classroom, positively encouraging the teacher in content gains, and back-and-forth discussions between the teacher and fellow, which aligns with the descriptions of secondary categories in the CA coding scheme (Glazer and Hannafin, 2008). The teacher grows from this partnership in both gain of new content and change in teaching practice. Similarly, the fellow learns pedagogy and classroom management from the teacher through the shared interactions. Thus, by comparing the two coding schemes, themes emerged from both that support the SCP as a collaborative apprenticeship model for teachers and fellows (Figure 3).

DISCUSSION

The SCP Program as a Unique Situated Collaborative Apprenticeship Model. The goal of this study was to examine the hypothesis that the SCP is a new model for a situated professional development experience for teachers and fellows that aligns with the Collaborative Apprenticeship model described by Glazer and Hannafin (2006). Similar to the CA model, the unique SCP CA model is built on the concept of reciprocal interactions that give rise to a mutually beneficial learning environment for scientists and teachers. Teacher interactions in the CA model work such that the novice teacher learns pedagogy from the mentor in a situated learning environment, effectively reaching mastery by the end of his/her participation. The mentor teacher grows in his/her practice by learning new methods from the novice teacher. Whereas teachers in the original CA model benefit mostly from interactions that target their teaching or pedagogy (Glazer and Hannafin, 2006, 2008), the teachers in the SCP model are novice scientists who benefit from learning new pedagogy as well as science content brought by the fellows. Through reciprocal interactions such as modeling, planning, and sharing ideas, fellows transfer their knowledge to the teachers (Zahorik, 1987; Chene and Sigouin, 1997; Kohler et al., 1999; Clement and Vandenberghe, 2000). Across the years of participation, the teachers' comfort of the subject matter matures to the point that she is able to incorporate more inquiry-based science into her lessons and can teach the content in more depth. From this, the teacher grows in her teaching practice and is able to modify the pedagogy to a less structured, more student-centered environment.

Through co-teaching, co-planning, and other reciprocal interactions, the scientist as the novice teacher grows in both pedagogy and classroom management skills (Korinek and McLaughlin, 1996; Hasbrouck and Christen, 1997; Selwyn, 2000; Hertzog, 2002). The end result over time is that the scientist is able to lead the classroom on his or her own, depending on the length of time in the program. The scientist transitions from novice to mastery in this model in pedagogy, as the teacher transitions from science content to mastery phases throughout the program. While this study focused mainly on the professional growth of the fellow in pedagogy and classroom management, this professional growth leads to the fellow's progress in communication skills and developing the skills necessary for a career in education either at the K-12 or collegiate level (Gamse et al., 2010; Bolger et al., 2012). Previous studies have focused on the fellows' growth in communication skills as a result of the GK-12 program (Stamp and O'Brien, 2005; Trautman and MaKinster, 2010; Ufnar et al, 2017), but very few have looked at the potential for career opportunities in education for science PhDs (Doyle and Vale, 2013). The SCP CA model presented in this study outlines a potential model that prepares science fellows for his/her future career that will require teaching, communication, and/or mentoring skills, including K-12 or college teaching.

From the comparison of reciprocal interactions from the CA model and the emergent themes from the case study presented here (Table 4), the information gathered suggests that

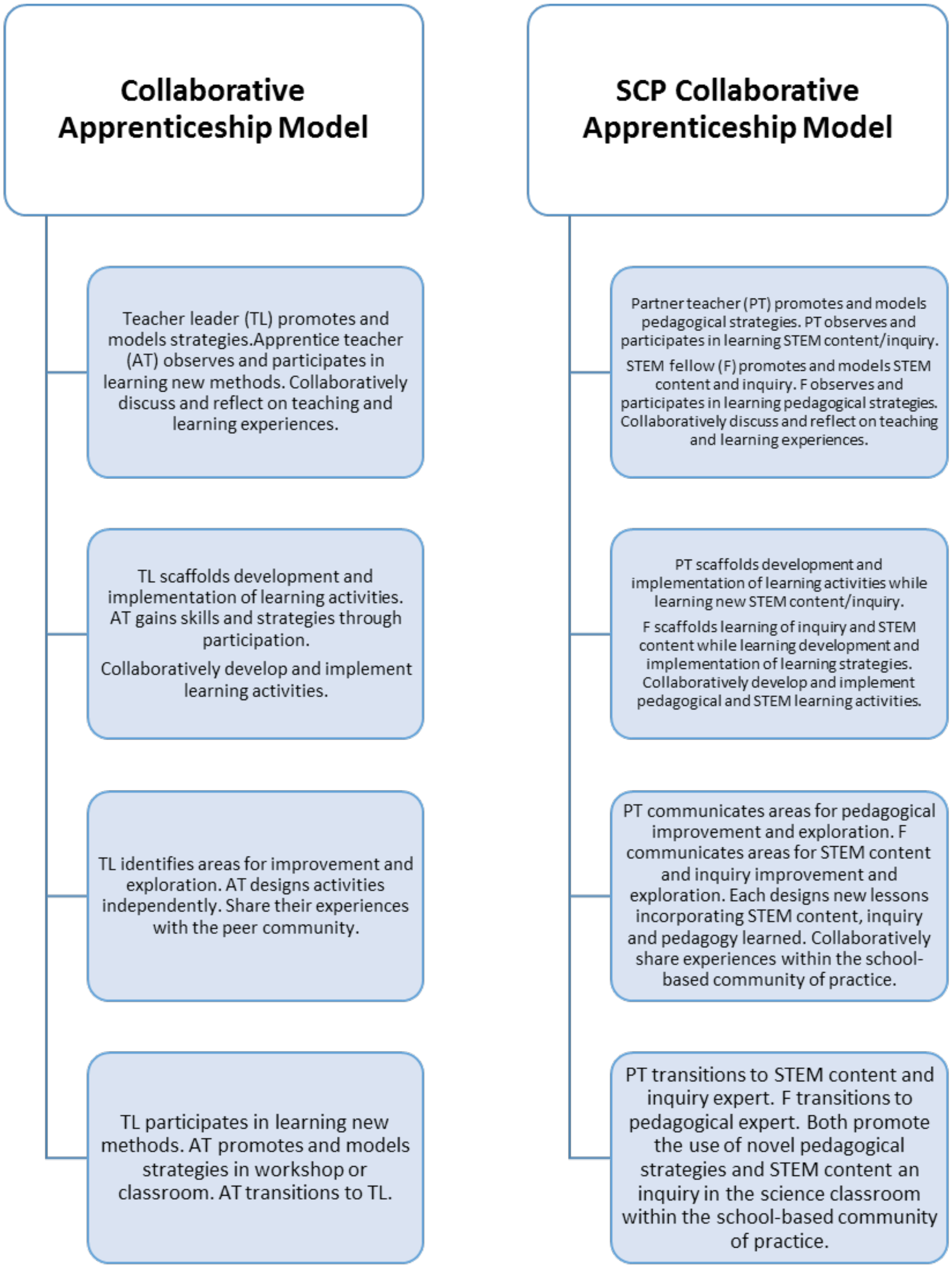

Figure 3. Alignment of the SCP CA Model with the CA Model developed by Glazer and Hannafin (2006).

the SCP CA model is a new situated learning environment (Lave, 1991) for teacher and fellow participants. To highlight the components of this new model, a comparison was made between the existing CA model by Glazer and Hannafin (2006) and the SCP CA model proposed in this study (Figure 3). In the Introduction phase of the CA model, the teacher leader will model strategies, and the novice or apprentice teacher observes and participates in learning new methods. Similarly, in the SCP CA model, the novice teacher (fellow) observes the partner teacher and participates in learning new methods in pedagogy and classroom management. However, in the SCP CA model, the fellow is also modeling new content and ways of incorporating that content into the classroom. Therefore, the teacher is also a novice in science content and learns from her fellow by observing and participating in learning new content. In the Developmental Phase of the CA model, the teacher leader scaffolds development and implementation of learning activities, and the novice teacher gains strategies through participating. In this phase, the two will collaboratively develop and implement the learning activities. Similar to this model, during the SCP CA, the novice teacher (fellow) has moved past the observation stage and will actively participate in both co-planning and co-teaching of the lessons. Through this participation, the fellow is learning new skills and strategies in the framework of planning and teaching the lessons.

The novice scientist (teacher) in the Developmental stage of the SCP CA model learns new science content through co-planning of the lessons and co-teaching those lessons with her fellow. She, as the lead teacher, is still modeling both planning and teaching strategies for the fellow, who is, in turn, modeling the science content for the teacher. As the scientist and teacher move into the Proficient phase, the scientist begins to propose using new science content to improve instruction and pedagogy and designs lessons on his/her own, similar to the apprentice teacher in the CA model who designs activities independently. Further, the mentor teacher in the SCP CA model is starting to incorporate new science content into the lessons that she has learned from the fellow. By the final phase of the model, the scientist is transitioning to the role of lead teacher or pedagogical expert in the classroom, while the teacher is participating in learning new methods and gains mastery in incorporating new science content into inquiry-based lessons.

Implications for Future Research

This study identified several factors that defined attributes of a successful SCP team and the potential for growth that happens across participation in the SCP program. From this, the SCP CA was proposed as a unique situated professional development model that is based on reciprocal interactions throughout the program that give teachers and scientists the opportunity to grow professionally in science content and pedagogy. The foundation of trust and respect that is fostered between the fellow and the teacher allows for a solid co-teaching relationship in the classroom. Students are learning science from a team that is composed of a science expert and a pedagogical expert that has the potential to impact the teaching and learning of science, not just for the students, but also the teachers.

The current study identified several implications for future research that would help to define the effectiveness of the SCP CA model as a professional development model for teachers and fellows. First, the CA model developed by Glazer and Hannafin (2006) focused on teacher growth within the framework of a community of practice. Defining and characterizing the reciprocal interactions within a community of practice for the SCP CA model would enhance the understanding how the model leads to continual professional growth for the teacher and fellow. Learning within the community of practice and focusing on how both participants are growing during the interactions may also help to define the parameters necessary for program success and enhancing the teaching and learning of science (Wenger, 1998).

Second, identifying and measuring teacher and fellow growth in both science content knowledge and teaching practice within the SCP CA would strengthen the model as a situated professional learning environment for teachers. Situated learning environments and cognitive apprenticeship models with legitimate peripheral participation have been shown to be critical to the success of teacher and scientist professional learning and learning within a real-world context (Brown et al., 1989; Lave and Wenger, 1990; Fullan and Stiegelbauer, 1991; Stewart and Lagowski, 2003; Dennen, 2004). Combining the two models such that the teacher and scientist are working together in a collaborative context (i.e. the SCP CA model) should allow for the identification of measures that will help define the teacher and fellow growth over participation in the program as that growth relates to situated learning and collaborative apprenticeship. Using these measures, we can more effectively tease out the growth that occurs in each stage of the model and identify the stages of movement from more of a cognitive to collaborative growth pattern to help refine the SCP CA model (Figure 3).

Third, there are many potential factors that may affect the efficacy of professional development models within the school environment. Issues such as last minute changes to the school day, lack of planning time, changes to teacher schedules, and systemic problems such as teacher attrition lead to issues of sustaining professional development models and communities of practice within and across schools (Johnson, 2006; Ufnar et al, 2017). These challenges within the context of the SCP CA model must be identified to overcome these issues and create an effective model for professional growth.

Finally, as the most important outcome for professional development in general, future work will focus on the growth of students in the SCP CA classrooms. Research has shown that students excel in inquiry-based science learning when teachers have greater content knowledge and strength in teaching practices (Darling-Hammond, 2000; Smith, 2009; Kanter and Konstantopoulos, 2010). Therefore, it is imperative to identify how students grow in their scientific knowledge in learning from both a teacher and a scientist, and how this growth translates as the student matriculates through to high school and college.

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The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript.

FUNDING SOURCES

This work is funded by an NIH SEPA Award (R25-GM129169). Program development was funded by grant awards from Jane's Trust, the Arthur Vining Davis Foundations, and the Petit Family Foundation. The TtGG program could not be accomplished without the help of numerous expert teachers across New England; the authors greatly appreciate significant contributions made by Barbara Farrell, Stephanie Dumont, and Laura Butterfield. Dana Waring and Marnie Gelbart at pgEd have provided expert ethics guidance or instruction each year. Ashley Greaves, a summer student funded through the Maine INBRE program (P20GM103423), developed and optimized the TAS2R38 assay.

ACKNOWLEDGMENTS

School year implementations would not be possible without the support of Alison Kieffer and Sarah Wojiski at The Jackson Laboratory.

ABBREVIATIONS

SCP: Scientist in the Classroom Partnership; CA: Collaborative Apprenticeship; NSF: National Science Foundationl MNPS: Metro Nashville Public Schools; PD: Professional development; PL: Co-planning; CT: Co-teaching; FCK: Fellow content knowledge; FTR: Fellow-teacher relationship; HOS: Hands-on science; TPK: Teacher pedagogical knowledge: ; TCK: Teacher content knowledge; AF: (T or F): Adaptability and flexibility; GP: Growth in practice; FPK: Fellow pedagogical knowledge; RS: Relationship with students; FCM: Fellow classroom management; TM: Time management; CDA: Communication to difference audiences; RP: Respect for partner

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