# Chapter 14
# Pedagogical Partnerships in Primary and Secondary STEM Education

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**Abstract** It is crucial to provide students with a strong grounding in STEM education to continue to advance and contribute to the technological world. Many students develop negative attitudes toward school-focused STEM subjects, particularly science and mathematics, and often become disenchanted with these subjects as they progress through the compulsory years of school. The way in which these subjects are taught has been identified as a key element in engaging students. In the primary school context, many teachers have limited specialised knowledge in STEM areas and often lack confidence in teaching some of the content they are expected to teach while in the secondary school context, teachers typically have strong content knowledge but do not necessarily employ effective teaching strategies or represent the content in abstract ways and often fail to make cross-curricular links. This chapter reports on a novel approach to STEM education professional learning, used as part of a school-based research project. The approach brought together primary and secondary school teachers to collaboratively program and team-teach science, resulting in reported improvements in the content knowledge and self-efficacy for the primary school teachers, and enhanced pedagogical knowledge for the secondary school teachers.

## 14.1 Introduction

Science, Technology, Engineering and Mathematics (STEM) education is viewed as essential for a sustainable and prosperous future. Nations turn to science to meet the threats to our environment, the health demands of an aging population, and to ensure the security of our food, water and power supplies (UNESCO, 2017). Further, a scientifically literate citizenry is seen as key for a strong economy

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(Marginson, Tytler, Freeman, & Roberts, 2013). Australian policymakers and business groups share this perspective, vigorously promoting STEM education as a way to ensure Australia's security and international competitiveness (Australian Industry Group, 2015; Department of the Prime Minister and Cabinet, 2015; Office of the Chief Scientist, 2013). Australia's various jurisdictions have responded by initiating an array of STEM strategies with the aim to improve student engagement and achievement in STEM education, including science education (Murphy, MacDonald, Danaia, & Wang, 2018). Both the generalist and specialist teachers of STEM are key in implementing such strategies and initiatives.

To engage and improve students' academic performance in STEM, confident teachers who have the discipline knowledge, skills and who are capable of implementing engaging pedagogies are needed. Most countries require both primary and lower secondary teachers to hold a similar tertiary qualification. The key difference between the qualifications is that primary teachers' education tends to have a larger component that is focused on pedagogical and practical training while lower secondary teachers' tertiary education tends to have a larger discipline focus. This may result in primary teachers with poor knowledge of the content they are required to teach, and lower secondary teachers' with inadequate pedagogical expertise to effectively teach the disciplinary knowledge (OECD, 2018).

The purpose of this chapter is to share findings from a 2-year Australian school-based research project that teamed primary teachers with specialist secondary science teachers for the programming and teaching of science. The project aimed to build the primary teachers' confidence and competence in teaching science and hoped to extend the secondary teachers' pedagogical skills. This chapter describes the collaborative programming and team teaching approaches adopted and highlights the impact the project has had on both the primary and secondary teachers' pedagogical content knowledge. The discussion reflects on how the programming and teaching approaches adopted in this science-focused project could easily be translated to the individual discipline areas of STEM or STEM as an integrated approach. Implications for the professional development of teachers of STEM are also considered.

## 14.2 Australian Context

In many countries, primary school teachers are reluctant science teachers, and this is often attributed to low self-confidence in science teaching and scientific knowledge (Appleton, 2008). Australian primary school teachers report a similar lack of confidence with science teaching (Aubusson et al., 2015; Burke et al., 2016), and, compared to other nations, Australian primary school teachers are less likely to have a qualification with a major in Science or Mathematics (Marginson et al., 2013). Research has found that primary teachers with poor science knowledge and science teaching confidence, teach science less often and use more traditional teaching methods (Alake-Tuenter, Biemans, Tobi, & Mulder, 2013; Aubusson et al., 2015;

Tytler, 2007; Tytler, Osbourne, Williams, Tytler, & Cripps Clark, 2008). This may in part explain the 2015 TIMSS findings that Australian Year 4 students spend only 57 h a year studying science, compared to an international average of 76 h, and only 22% of teachers emphasised scientific investigation in the majority of their science lessons (Thomson, Wernert, O'Grady, & Rodrigues, 2017).

This relatively poor state of Australian primary science education is exacerbated by the impact of inadequate resourcing and time for science education in Australian primary schools (Goodrum & Rennie, 2007; Thomson et al., 2017). Further, time to prepare for science teaching, and having access to adequate classroom time for science education, are commonly seen by teachers as significant barriers to effective science education (Burke et al., 2016). Goodrum and Rennie (2007) argue that appropriate resourcing, along with professional learning, is a requirement for improving primary school educators' science teaching capacity and confidence. So there seems to be a complex range of interacting factors resulting in science education not receiving the attention it requires in Australian primary schools (Albion & Spence, 2013). Access to appropriate resources coupled with competent, confident teachers capable of implementing engaging pedagogies are needed in order to engage students in school science.

Secondary science teaching in Australia fares better in terms of teacher content knowledge and resourcing, but still faces some deficits in science pedagogy. The 2015 TIMSS found that 84% of Year 8 students were taught by a teacher with a major in science, slightly higher than the proportion internationally (Thomson et al., 2017). Year 8 students spend 126 h per year studying science, compared to an average of 144 h per year across the countries studied. Only 10% of Australian Year 8 students were taught by teachers reporting moderate to severe resourcing problems, compared to an average of 23% internationally. Despite being better placed in terms of content expertise and resourcing, secondary teachers do not necessarily employ effective teaching strategies or represent the content in abstract ways and often fail to make cross-curricular links (Danaia, Fitzgerald, & McKinnon, 2013). It would seem that strong pedagogical content knowledge (PCK) is needed for the effective teaching of school science (Appleton, 2008; Houseal, Abd-El-Khalick, & Destefano, 2014).

## 14.3 Pedagogical Content Knowledge

The construct Pedagogical Content Knowledge (PCK), was first coined by Shulman (1986), who defined it as

> … the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations — in a word, the most useful ways of representing and formulating the subject that make it comprehensible to others … Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics

> and lessons … that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding. (p. 9)

In essence, the construct PCK is a model of teacher knowledge (Grossman, 1990). The knowledge base is something that teachers develop over time and comprises much more than just knowing and delivering the subject content to students. Cochran, King, and DeRuiter (1991) defined PCK as "the manner in which teachers relate their pedagogical knowledge to their subject matter knowledge in the school context, for the teaching of specific students" (p. 1). PCK encompasses the following components: knowledge of students and their conceptions; knowledge and beliefs about purpose; knowledge about the curriculum; knowledge of content; and, knowledge of appropriate teaching strategies (Shulman, 1986; van Driel, Verloop, & de Vos, 1998).

PCK is essential for effective teaching and learning to occur. This requires teachers to be well adept at all of the components of PCK in their teaching. An effective teacher of science with high PCK would be experienced in moving through the various components of PCK and would make changes to their teaching based on their PCK to cater for the needs of their students. Abell (2007) presented a model of PCK for teaching science. In this model, Science Subject Matter Knowledge (comprising science syntactic and substantive knowledge), Pedagogical Knowledge (comprising curriculum instruction, educational aims, classroom management) and Knowledge of Context (comprising knowledge of students, the school and the wider school community) were three key elements that were identified as essential for effective PCK in teaching science. The model highlighted the interrelated nature of the components of PCK and explored how these elements interacted. One could assume that primary teachers would have strong pedagogical knowledge based on their tertiary training while lower secondary science teachers would be more inclined to have much broader and deeper science subject matter knowledge. One would anticipate that both primary and secondary teachers would both have knowledge of context. Given the importance of teachers having all of the elements of PCK for the successful teaching of science, it would be interesting to examine how primary and junior secondary teachers of science could work together to strengthen all of the elements of their PCK.

## 14.4 Collegiate Professional Learning in Science Education

Teacher collaboration and mentoring are potentially valuable contributors to improving science teacher capabilities. Opportunities for collegiate collaboration and participation in effective science teaching practices can contribute to building teacher self-efficacy and pedagogical content knowledge in science education (Mansfield & Woods-Mcconney, 2012). Conversely, a lack of time and opportunities to collaboration with colleagues is seen by primary school teachers as a significant impediment to effective science teaching (Burke et al., 2016). Mentoring is one form of collaboration suited to the development of improving the practice of science teachers (Bradbury, 2010). Mentoring between teachers has also been shown to contribute to teacher confidence and science pedagogical knowledge (Forbes & Skamp, 2016; Koch & Appleton, 2007). Forbes and Skamp (2016) investigate a mentoring arrangement not prominent in research, where secondary school science teachers mentor primary school teachers as part of the *MyScience* program. The findings of this research suggest that these mentoring relationships can positively impact on the beliefs and practices of mentor and mentee (Forbes & Skamp, 2014, 2016). The primary school teachers reported a changed understanding of what science education looks like in a primary classroom, as well as increased adoption of student-centred inquiry pedagogies (Forbes & Skamp, 2014). Similarly, the secondary science teachers involved in the project reported trialling more student-centred approaches with their Year 8 students, as well as developing a deeper understanding of the primary education context that then informed their work with Year 7 students (Forbes & Skamp, 2016).

Collaboration can extend beyond mentoring to include co-teaching. Effective co-teaching involves shared preparation, instruction, assessment and reflection, and requires strong communication and conflict management skills (Brown, Howerter, & Morgan, 2013). McDuffie, Scruggs, and Mastropieri (2007) conducted a review of 32 qualitative studies of co-teaching finding that teachers and administrators alike view co-teaching positively, with perceived academic benefits for students and professional benefits for teachers. Co-teaching may take several forms, including teach and assist (one teacher leads instruction while the other assists students as required); station teaching (teachers take responsibility for delivering different parts of the instructional content); parallel teaching (teachers divide the class and deliver the same instructional content); alternative teaching (one teacher instructs most of the class while the other withdraws a small group for support or extension); and team teaching (teachers collaborate to deliver the instructional content together) (Lusk, Sayman, Zolkoski, Carrero, & Chui, 2016). Research suggests that the ‘teach and assist’ model of co-teaching is most common, with ‘team teaching’ occurring least often (Pancsofar & Petroff, 2016). This is despite team teaching being viewed as the most effective form of co-teaching (McDuffie et al., 2007). There is limited research on the impact of co-teaching in science education.

Research suggests that effective professional learning that builds science pedagogical knowledge and allows teachers to experience successful science instruction could help redress some of the current deficits in primary science education (Burke et al., 2016; Deehan, Danaia, & McKinnon, 2017; Mansfield & Woods-Mcconney, 2012). Mentoring arrangements between primary and secondary teachers is one promising, but under-researched mechanism for delivering this professional learning (Forbes & Skamp, 2014, 2016) where primary teachers may have stronger pedagogical knowledge and secondary teachers may have stronger content knowledge (OECD, 2018). There is potential to extend this mentoring arrangement to include co-teaching (Lusk et al., 2016). While there is evidence supporting the positive impact of co-teaching in general classrooms (McDuffie et al., 2007), there has been minimal research into the impact of co-teaching on science education.

The school-based project examined in this chapter, informed by the aforementioned research, linked primary teachers with secondary science teachers for the programming and team teaching of primary science. The project aimed to build both primary and secondary teachers' PCK in the science curriculum area and in turn improved the primary teachers' confidence in teaching science and improve student outcomes and experiences in school science.

## 14.5 Context for This Research

The context for this research is a school-based science project implemented within a K-12 independent, coeducational day and boarding school. The school has over 1100 students and 305 staff. The primary and secondary departments are located on one campus but tend to work and operate in isolation from each other. Over the years, there had been very little, if any, opportunities for collaboration around programming and teaching. Before commencing the 2-year project, the primary teachers at the school indicated they lacked confidence in teaching the new national science curriculum and wanted professional development opportunities to help them teach investigative, inquiry-based primary school science. This became the stimulus for school-based collaborative programming and teaching of primary science project.

The project aimed to build primary teachers' confidence and competence in teaching inquiry-based school science by providing them with targeted specialist support and resources. Primary teachers were linked with specialist secondary science teachers for the programming and teaching of primary science. The teachers also had access to a science laboratory and specialised resources for the teaching of science. The secondary school science department had a focus on improving the instructional strategies employed to teach science in an attempt to try to make secondary science more engaging for students. It was anticipated that school-based project could also result in positive outcomes for the secondary science teachers involved. That is to say, by teaming-up the primary and secondary teachers, it was hoped that the primary teachers would help inform the secondary teachers of different instructional approaches and cooperative learning strategies that they tend to employ within their primary classrooms and which could be used and/or adapted for the secondary school context. Consequently, the research also investigated the impact of the project on the secondary science teachers involved. In particular, whether or not their involvement in the project informed or changed their practice of teaching science.

In the school-based project, students would be taught the Primary Connections curriculum materials designed by the Australian Academy of Science and which are mapped to the content of the National curriculum (Australian Academy of Science, 2019). The materials were supplemented with lessons that were constructed in the collaborative programming of the science content. It was anticipated that by having the primary and secondary teachers work together, it would hopefully ensure a developmentally appropriate continuum of learning in science within the school. The collaborative programming and team teaching approaches in implementing science were to be investigated to see what impact this had on student outcomes so that ultimately, improvements could be made to the way in which science was implemented and experienced at school. As part of the school-based project, students would be conducting experiments and practical experiences both within their classroom and within a science laboratory. The junior school had access to a science laboratory that is onsite (1-minute walk from their classroom). The location of where experiments and practical experiences were conducted was dependent on the lesson focus and content to be covered. The decision was up to the teachers implementing the experiences.

The purpose of the research underpinning the 2-year school-based project was to investigate the impact of these approaches on both teachers and students. There were three main research questions that were investigated within the larger project:

1. What impact does the collaborative team teaching and programming have on primary teachers' confidence and competence in teaching science?
2. What impact does the project have on the pedagogical approaches adopted by secondary school science teachers?
3. What impact does this approach have on students' knowledge outcomes and experiences in primary school science?

This chapter focuses on the impact of the approaches adopted on teachers' confidence and competence and on their pedagogical approaches in teaching science. The impact of the project on student outcomes (research question 3) will be the focus of a subsequent paper.

## 14.6 Research Design and Participants

A mixed methods approach was adopted for this research. Specifically, a Type-II Case Study (Yin, 2003) employing a pre-test/post-test design was used to investigate the impact of the project on teachers and their students. Questionnaires, semi-structured interviews, teacher programs, teacher reflections and student work samples were used to collect data from participants at different time intervals throughout the project (pre, during and post). This allowed comparisons to be made at different points in time across the project.

Within this research design, participating teachers also employed action research (McAteer, 2013) to reflect on the approaches they were using and to make changes to how they programmed, and team-taught future science units. In essence, results from the research coupled with information from teacher reflections were used to inform future cycles of implementation. The action research component was key in trying to ensure the sustainability of the project and in better informing future implementation through an iterative process.

A phased implementation approach was adopted to conduct this research project. This enabled the project to be introduced to different year levels and classes in different school terms. This allowed comparisons to be made between and within implementing and non-implementing classes to try to get a sense of the impact of the collaborative approach to programming and team teaching. It also provided a means by which to make the project scalable by gradually rolling it out across other classes.

The participants for this research comprised three groups: primary teachers; secondary science teachers; and primary school students. Over the 2-year period, 10 primary school teachers, three secondary school science teachers and 234 primary school students agreed to participate in the research. This paper focuses on the data collected from the 10 primary school teachers and three secondary school science teachers.

## 14.7 Collaborative Programming Days

Teachers were involved in a number of collaborative programming sessions that involved the primary teachers working in collaboration with the secondary science teachers. The collaborative programming sessions were held before the start of each school term. Primary and secondary science teachers were released from class and spent the day preparing the primary school program for the subsequent school term.

Over the course of the project, a total of eight professional learning programming days were held. As mentioned earlier, teachers would build their programs around the Primary Connections curriculum materials designed by the Australian Academy of Science (Australian Academy of Science, 2019). These units were already mapped to the National Science Curriculum and by using a 'base' unit, it allowed comparisons to be made with classes who were not involved in the team teaching approaches. During the programming sessions, the primary and secondary teachers spent time extending some of the lessons and/or modifying them to make them more inquiry focused and involve students in investigative science. The secondary teachers would examine each lesson in relation to the discipline content being explored and the primary teachers would share their insights into some of the pedagogical approaches that could be used with their primary students.

At each of these professional learning sessions, the academic mentor who was external to the school and who was responsible for conducting the research associated with the project was present. The academic would help facilitate some of the conversations between teachers. There were also opportunities for reflection built into these days. Where teachers were asked to reflect on what was working within the project, what could be improved and they were asked to share how they were feeling in relation to the project at that point in time. At some of the professional learning programming days, the academic reported on some of the student and teacher data that were collected within the project. This allowed teachers the opportunity to reflect on it and use it to inform the next wave of programming.

## 14.8 Data Collection Methods

Multiple quantitative and qualitative data sources were collected from participants over the 2 years of the project. Specifically, interviews were conducted with both students and teachers. Teachers also completed an online reflection and feedback form on two occasions while students completed questionnaires about their perceptions of science lessons at school. Students also completed pre and post-occasion questions related to the science content covered over the course of each school term. For the purpose of this chapter, the teacher interview data coupled with the teacher reflection data are used to highlight the impact of the collaborative programming and team teaching approach on teachers and their students. The student data will be the focus of a future paper.

### *14.8.1 Teacher Interviews*

All interviews were semi-structured where there was a list of preprepared questions to guide the interviews. Teacher interviews were conducted in two different grouping situations that is, on an individual basis or in focus groups based on the composition of the teaching team. The length of teacher interviews ranged from approximately 20 to 30 min. All interviews were digitally recorded and were transcribed by a transcription agency. The interview data are used to gain insight into participants' thoughts and feelings about school science and to depict student and teacher perceptions of what was happening in science lessons during the project.

### *14.8.2 Teacher Reflections and Feedback*

Teachers completed an online reflection and feedback form on two occasions. This form comprised the following questions:

1. What has worked for you in the collaborative science project (what have you liked)?
2. What has not worked for you in the collaborative science project (what have you disliked)?
3. What could be improved for you?
4. List three things you have learned during the project.
5. List three things you need to know more about.

The form was accessible via a survey monkey link and distributed to teachers during the final school term in the first year (2017) and during Term 3 of 2018. Teachers were asked to complete the form based on their experiences in the collaborative science project in each of the respective years.

## 14.9 Data Analysis

Thematic analysis was used for teacher interview and feedback data. Interview transcripts were read and coded for common themes within and across responses. NVivo (QSR, 2010) software was used to support the thematic analysis. Themes, counts and examples of responses are used to illustrate participants' thoughts and perceptions of what was happening in science during the project.

## 14.10 Teacher Results and Findings

The results below compare and contrast teacher perceptions and responses. The subheadings used represent the areas that were discussed in interviews or covered within the teacher refection and feedback forms. Where appropriate, direct comments from interview scripts and feedback forms are presented to illustrate teacher perceptions of, and experiences in, the project. The results shed light on the impact of the project on teachers' PCK in teaching science.

### *14.10.1 Things That Seemed to be Working*

Collaboration was a key theme identified as something that was working well within the project. During the project, teachers collaborated on the programming of science units and in the teaching of them. The collaborative nature of this process is reflected in the following teacher quote: "*there was a lot of collaboration, so there was a lot of talking about "what if" and "could we do this" and "would that work*". In the 2017 interviews, four teachers made 10 references to how well-received the consultation and collaboration elements of the project had been while in 2018, four teachers made reference to the collaborative elements of the project that were working well for them.

Confidence and knowledge were two themes often used interchangeably within teacher interviews. It was evident across the 2017 and 2018 interviews that many of the primary teachers involved felt they had increased confidence in teaching science and that their knowledge and/or science vocabulary had improved as a consequence of working with the secondary science teacher in the project. The following quote from a primary teacher reflects how they felt the team teaching approach was helping to build their confidence in teaching science and their knowledge of content.

> For me, it's just like me feeling more confident. … I feel like I've learnt something and I am able to now confidently talk about heat and it being produced by certain sources and all of that sort of stuff. I feel the highlight for me is that I have grown so much this term and when I see the kids using the language that they're using… and not even necessarily just in science lessons. …It's really great to hear the language and see the understanding and the sorts of things that they're coming up with in science. That sort of excites me because you

think, oh, … they're actually … it's sinking in, whatever we've been teaching them. I would say that that's a highlight too.

Table 14.1 presents a selection of interview quotes from the primary teachers that related to improved confidence and/or competence in teaching science. In the 2017 interviews, six teachers made seven references to improve confidence and/or competence in teaching science while five teachers made seven references in the 2018 interviews.

Student engagement and enjoyment was also identified as an important theme under what was working within the project. In the 2017 interviews, five teachers made six references to student engagement and enjoyment while six teachers made five references to this theme within the 2018 interviews. The following quotes reflect the nature of this theme:

There's a definite interest in the children, you can see they're very focused on the task and the investigations and they're loving … I think they see themselves working as scientists.

I said the other day, there's no science today, and [sigh] so it was a negative response, which is a positive really.

There were some things that the kids just loved. I really find that, in general, the kids in year [class removed] still are really enjoying science.

**Table 14.1** Confidence and improved knowledge example quotes from teacher interviews

| |
|---|
| *2017 examples of quotes* |
| I think my confidence with teaching the subject area. I'm really confident to pick up that material and know that I'm telling them, sort of scientifically I'm telling them the correct thing |
| I saw myself as being a bit hopeless with the whole science thing and just listening to the language and the vocabulary that they used was really helpful for me |
| I really like having [secondary science teacher] come into the room and hearing the sorts of the correct language or the vocabulary to use |
| I think that [secondary science teacher] enthusiasm for science has certainly got me a bit going, because really science wasn't something that I loved to teach, so I think that that's been useful |
| And the other thing is the language, the language that we're using, we're talking about chromatography, we're talking about heterogeneous and homogenous solutions and some mixtures |
| *2018 examples of quotes* |
| I'm certainly loving having [secondary science teacher]—that expertise, that real science knowledge, that's great. That's helping me, I feel, with questioning and working with the children |
| If you've got someone else coming into the room that can help explain that and that's their field of understanding, it helps you then understand |
| I think my confidence has definitely grown. I probably make sure that I fit the Science in, whereas before, prior to the project altogether, I may have gone, "Well, I can't fit that in so we won't actually do that this week" |
| I know for myself now I'm teaching science a lot better than what I was |

In analysing teachers' responses to the feedback forms, comments were grouped based on the type of teacher participant involved (i.e. primary or secondary teacher). Consistent with the interview results, it was evident that the primary teachers felt the collaborative programming coupled with the team teaching aspect was invaluable. Having access to a discipline expert appeared to be worthwhile and beneficial for many as highlighted in the following primary teacher response: "*I liked team teaching with the Science high school teachers as they were able to give more scientific definitions and information. It also helped me to understand some of the content better.*"

Similarly, the secondary teachers felt the collaborative programming worked well within the project. Evident in some of the secondary teachers' responses was also an element of personal satisfaction that related to teaching the primary students. For example, "*Prep staff have helped me to understand progression from prep-high school." "Programming was invaluable. Having the time to collaborate and plan together is the best part of this project, as we all learn from each other. By planning together, we all have buy in and understand where the program is going and what we are doing*."

### *14.10.2 Things That Were Not Working*

Time was identified as a major theme across both teacher interview occasions and within the reflection and feedback forms. Teachers seemed to want more time to work on the collaborative programming before the start of a unit. It was also interesting to note that teachers wanted time at the end of a unit to be able to critically reflect on what had happened over the term and to allow them to make changes to the program for future implementation. The following three quotes illustrate the nature of this theme.

> More time to collaborate with the high school teachers.

> We went and printed the unit off and I remember looking at things, thinking, "Oh, no, that didn't work. We needed to change that," and we didn't have the opportunity to do that.

> More collaborative planning time and time built into review the data collected to be able to shape the direction of learning for different cohorts would be beneficial. Even time allocated to review units of work while they are fresh - to add in or take out activities would be helpful.

Timetabling was also a theme that was identified as a constraint or was of concern across the teacher interviews and within the feedback forms. The scheduling of science lessons within the primary school had to fit within the constraints of the secondary school timetable given some of the secondary science teachers were involved in the team teaching of lessons. The following quotes capture what teachers were saying in relation to this theme.

> I think the main thing that probably inhibits people is probably the flexibility with timetable.

> I think timetabling is a huge roadblock and the time allocated to be able to do this, so I guess it would be nice to see a little bit more importance placed on it.

### 14.10.3 Things Teachers Would like to See Continued

During the project, teachers' feedback helped inform the next iteration of the project. In the 2017 interviews with teachers, it was evident they wanted the collaborative programming to continue. Many of the primary and secondary teachers asked for additional time to be devoted to collaborative programming. This also seemed to be a top priority for respondents across the 2018 interviews. The majority of teachers in the 2018 interviews indicated that going forward, they wanted to see the collaborative programming continued and more time devoted to this before the start of a unit and at the end of a science unit to allow reflection and feedback to inform the next iteration of the unit of work.

The 2017 interviews revealed that two of the primary teachers and two secondary teachers involved in the project indicated that they would like better access to the science laboratories for their primary classes. There were two reasons offered for why these teachers wanted more access to the labs. First, they felt students would be *more excited* if they went to the labs. Second, the labs contain the equipment needed for lessons so there would be less time spent on sourcing and organising equipment. It is interesting to note that in the 2018 interviews, teachers did not mention the science laboratories as a priority going forward. Rather, their responses focused on the collaborative programming, extending the project to other year levels (continuum of learning—including the transition to high school) and continuing with aspects of the collaborative teaching.

### 14.10.4 Team Teaching Approaches

During the interviews, the teachers gave descriptions of their team teaching approaches. It was evident that there were different approaches used across the classes. There were some who appeared to work collaboratively together on all aspects and felt comfortable building on each other's ideas and approaches during lessons. This relationship seemed to develop and prosper over time.

> [Secondary teacher name] and I are very comfortable with each other so we just jump in and take off from wherever we left and I'm finding that easier and easier as it goes along but I'm also far more confident just to go, "Well hang on a minute, let's just come back a bit," or you know because sometimes [secondary teacher name] jumps in at a level that's a bit higher or sometimes even ask, "Where will we start?" and you know then I will say, "Now where are we going from here?" … So I'm finding the team teaching really, really good … The kids love it and we're able to split in the groups and both give really solid feedback to the kids.

There were those who highlighted the benefits their expertise brought to the lessons. Some of the primary teachers indicated they felt the secondary teachers helped with the content while they helped translate this content to an appropriate level for their primary students.

> It's just great having [secondary science teacher] there because he can pose questions and give information that I wouldn't necessarily have thought of, not being a science teacher.

> We really have bounced off each other in terms of the information that we both get I think in terms of delivering the lesson. I've sort of, in terms of talking with the kids and pitching it at their level, there's a few things that I've been able to bring to [secondary teacher name], so I talk about tools in the classroom.

Some of the secondary teachers indicated that the team teaching experience really made them stop and think about the purpose of their lessons. Some also felt there were things they could apply to their secondary science classes.

> It certainly makes you refocus on what the important point of the lesson is… It makes you stop and think about what's your main point in the lessons you're teaching up in senior school or are you just going all over the place that the kids in senior school can't connect the dots? … I think it's been really good because it actually makes you stop and think about how you explicitly instruct things, because I'm so much with senior kids you forget that you actually have to have a sequence of instructions.

A reflection from a participating secondary teacher indicated that their involvement in team teaching made them think about how they teach their secondary students. They have started to reconsider some of the scaffolding and pedagogical approaches that could be employed within their secondary science classes. The following quotes are from one of the secondary science teachers who was involved in team teaching.

> These kids were using, we were using words like homogeneous, heterogeneous, words like that, that when kids get to Year 7 we assume that they don't know. So that's been a real eye opener for me at the other end. We just kind of assumed that the kids get to Year 7 pretty much not knowing anything but … there is a fair bit that the kids do know, well from what I've seen at least at the primary level.

> I see a completely different angle to the kids and I think I just made assumptions about kids in primary schools without having ever really experienced it. And it's given me a few things to think about, and it kind of changes my approach to my Year 7 class … So I'm getting just as much out of it as [the primary teacher] is.

### *14.10.5 Things Teachers Had Learned*

Teachers were also asked to reflect on things they had learned during the course of the project. It is interesting to note that many of the primary teachers commented on knowledge or competence related aspects that they felt they had learned. The following are some examples of the primary teacher responses for what they learned during the project: improved subject content; scientific knowledge base has increased;

new science vocabulary and terminology; better understanding of scientific diagrams; deeper knowledge of science outcomes; knowledge of using data for teaching has increased; ideas for practical activities; and, how to draw and annotate a science diagram.

Secondary teachers identified aspects that related to how they teach and would often make links with the secondary school context. The following are some examples of some of the secondary teachers' responses of what they learned during the project: ability to provide learning across faculties; teaching methods for prep kids; more of an idea of high school transition needs; persistence and behaviour management; and, importance of allocating time for programming.

## 14.11 Discussion

Similar to other countries, the Australian National Curriculum for all years of compulsory education requires inquiry-based science to be implemented. Many primary teachers often lack the content knowledge needed in order to teach the content of the science curriculum. This often results in them having a lack of confidence in teaching science. Secondary science teachers tend to possess strong content knowledge in their specialist area but often fail to implement effective teaching strategies. This chapter reported on a school-based research project that linked primary and secondary science teachers for the programming and teaching of primary science in an attempt to build the aforementioned areas of teachers' PCK in science.

The teacher interview results coupled with their reflections on the feedback forms suggest that the collaborative approach to team teaching and programming positively impacted their confidence and competence in teaching primary science. Many of the primary teachers reported that they felt they had increased confidence in teaching science and that their knowledge and use of science vocabulary had improved as a consequence of working with the secondary science teacher in the project. The collaborative programming and team teaching opportunities appeared to strengthen the primary teachers' knowledge of science content and equipped them with the necessary skills to develop and/or locate, modify and implement future inquiry-based science activities for their students. These findings are consistent with other literature (Forbes & Skamp, 2016; Houseal et al., 2014) where collaboration and mentoring between primary teachers and secondary teachers or primary teachers and scientists has contributed to increased confidence and science content knowledge for primary teachers.

The teacher interview results revealed that for some of the secondary teachers, involvement in the project made them reflect on the purpose of each science lesson they taught; both in the primary and secondary school context. Another also indicated they were planning to make some changes to how they would normally work with their Year 7 students as they were now aware of the content covered within primary school and how capable primary students were in learning science. These findings are consistent with others that have been reported in the literature where secondary teachers who have mentored primary teachers have reported having a deeper understanding of the primary education context that then informed their work with Year 7 students (Forbes & Skamp, 2016).

While there were some limitations to this research, the collaborative approach to programming, coupled with the team teaching of lessons, appeared to bring together the primary teachers' understanding of their students and various pedagogies and the secondary teachers' knowledge and skills in specific science discipline areas; two key elements of PCK needed for the successful teaching of science. Knowledge of content and knowledge of pedagogical approaches are key elements of PCK needed when teaching other STEM discipline areas. Thus, the approaches adopted within this school-based project could certainly be applied to Technology, Engineering, Mathematics and/or integrated STEM education. There is the potential for collaborative pedagogical partnerships to be formed within other STEM discipline areas.

Wheatley and Kellner-Rogers (2015) maintain that successful STEM learning environments require teachers to collaborate. They highlight the need to create collaborative communities of trust where teachers can take risks in their STEM teaching while learning together with other teachers. Strong relationships were formed between the primary teachers and secondary science teachers within this project. There was evidence to suggest that through the collaborative approach to programming and teaching, they learned alongside each other. The teachers continue to engage in professional dialogue about science and they are planning to continue this collaborative work in the future and possibly extending it to other curriculum areas. Given this project was set in the context of the primary school, more research is needed in the secondary school context to see how these secondary teachers translate some of what they have learned in this project into their secondary lessons.

The professional learning approach used in this project involved teachers working collaboratively together over a sustained period of time. They had the opportunity to model approaches and learn from each other in an ongoing capacity. Many of the elements contained within the professional learning approach adopted within this project are consistent with characteristics of other STEM professional learning models. Watson, Beswick, and Brown (2012) present a framework of professional learning for mathematics teachers. The framework comprised eight elements: teachers identifying issues; knowing learners and their characteristics; ownership by the participants; connected to the school context; sustained overtime; developing links between theory and practice through modelling; balancing individual and school community needs through collaborative participation; and, evaluation using student learning as an outcome. There are certainly parallels that could be drawn in relation to each of these eight elements and the characteristics of the school-based project described within the chapter.

The approaches adopted within the school-based project described within this chapter could be considered as a sustainable professional learning model for building teachers' PCK in STEM. There are very few similar examples of STEM professional learning for teachers represented in the literature, making combined use of mentoring and team teaching to build teacher capacity in STEM education. In this project, secondary and primary school teachers worked together to plan *and* deliver science programs for primary school students. In essence, a teacher community of practice (Wenger, 1998), centred on the programming and the teaching of primary science was created. The findings from this project suggest that this model builds content knowledge and self-efficacy in science for primary school teachers, while contributing to the pedagogical knowledge, particularly as it relates to student prior understanding and readiness, for secondary school teachers. Further, participants felt that the program had a positive impact on the quality of student learning in science in the primary school classes.

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